BBC

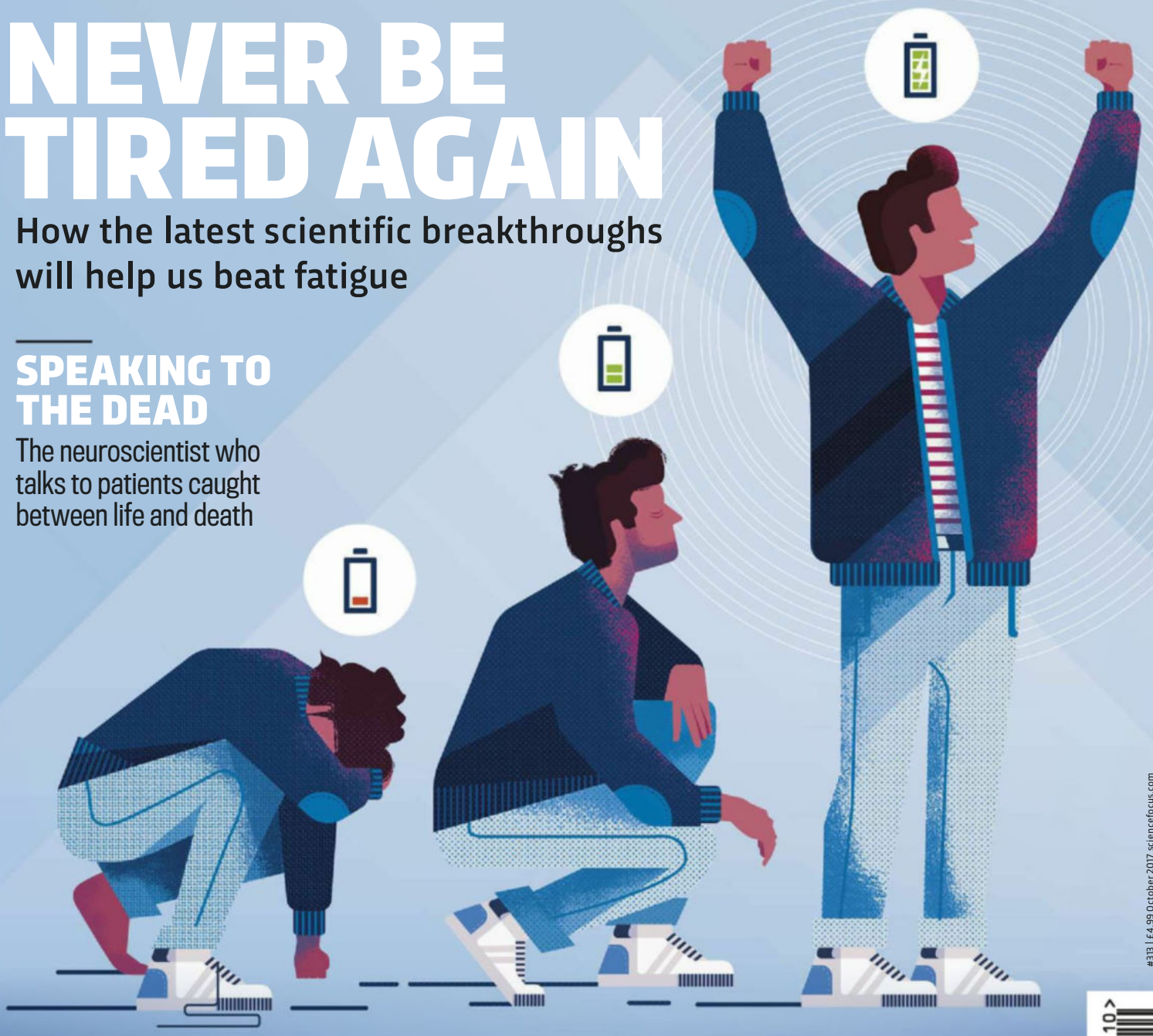
SPACE TOURISM WHY IT'S FINALLY A REALITY

FOCUS

SCIENCE AND TECHNOLOGY

NEVER BE TIRED AGAIN

How the latest scientific breakthroughs will help us beat fatigue



SPEAKING TO THE DEAD

The neuroscientist who talks to patients caught between life and death

"THE DAY MY BRAIN BROKE"

HOW OCD AFFECTS THE MIND

THE MAN WHO PREDICTED CLIMATE CHANGE 200 YEARS AGO

#313 | £4.99 October 2017 sciencefocus.com

9 770966 427166 10>

D7500

Nikon 100th anniversary

I AM CHASING MOMENTS

4K UHD Bluetooth Wi Fi CERTIFIED

I AM THE NEW NIKON D7500. Don't let a great moment escape you. Equipped with a 20.9MP DX-CMOS sensor, 51-point AF and ISO 100 to 51200, the new Nikon D7500 can achieve stunning images in low light and has a continuous shooting speed of 8 fps. Wherever you move, an intuitive, tilting touch screen and slim body with deep grip offer added agility, and you can share your images in an instant to your smart device*. Alternatively, capture movies in incredibly sharp 4K UHD to relive again and again. Go chase. **nikon.co.uk**

*This camera's built-in Bluetooth® capability can only be used with compatible smart devices. The Nikon Snap-Bridge application must be installed on the device before it can be used with this camera. For compatibility and to download the SnapBridge application, please visit Google Play® and App Store. The BLUETOOTH® word mark and logos are registered trademarks owned by Bluetooth SIG, Inc. and Google Play® is a trademark of Google Inc.

Nikon

At the heart of the image

You can make **crisps from jellyfish** → p17

WELCOME

I don't know about you, but I'm exhausted. Not just sleepy, but weary. The kind of tired where your head feels like it could drop off at any minute and roll its way back into bed. The chances are some of you reading this will feel the same way. According to the Royal College of Psychiatrists, one in five of us feels unusually tired at any given time. Around 20 per cent of visits to GPs are made by patients complaining that they feel tired all the time, and they don't know why. Doctors have a shorthand for it: TATT.

In my case, though, I know who's to blame. It's the bloody seagulls! Just before dawn, in what I now assume is a Satanic ritual, swarms of Bristolian white terrors whip themselves up into a screeching whirlwind just outside my block of flats. Needless to say it gets me up before my alarm, and I'm not a fan. Fortunately for me, respite is within reach. As winter creeps in, the birds seem to move on, possibly to haunt some other poor soul, and I can finally get an uninterrupted night's sleep. Sadly, the same isn't true for most people. They get their recommended eight hours each night, eat healthily and exercise regularly – but they still feel tired. They just walk around with an invisible black hole sucking up all their energy, and it seems to get worse and worse. If this sounds like you, then turn to p38 to find out how scientists are trying to get the better of fatigue, and see p42 for some tips on how to get your spark back.

Finally, it's OCD awareness week from 8-14 October. It's a global effort to raise understanding about the condition, and in that spirit our editorial assistant James Lloyd shares his experience of the condition and the science behind it. Turn to p60 to read on.

Daniel Bennett, Editor

IN THIS ISSUE

PHILIP BALL
Philip Ball is a presenter on BBC Radio 4's *Science Stories*. This month, he reveals how Alexander von Humboldt predicted climate change over 200 years ago. → **p67**

HAYLEY BENNETT
Gender isn't necessarily binary by nature. Hayley Bennett introduces us to creatures that have not two but three, four or 28,000 different sexes. → **p56**

ADRIAN OWEN
Neuroscientist Adrian Owen uses brain imaging to 'speak' to patients in vegetative states. He talks about his work in this month's interview. → **p74**

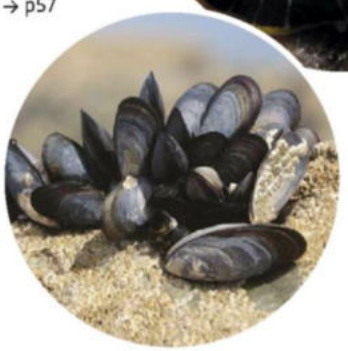
COVER: MAÏTÉ FRANCHI

WHAT WE'VE FOUND OUT THIS MONTH

Astronauts' stale breath and urine could be the key to longer space flights → p21

Inspired by Iain M Banks, SpaceX has called its drone landing platforms Of Course I Still Love You and Just Read The Instructions → p46

Tiger flatworms use their sex organs as swords to stab each other. This is known as 'penis-fencing' → p57



The chemical that helps mussels stick to wet rocks is being investigated for use as a surgical glue → p81

CONTACT US

Advertising
neil.lloyd@immediate.co.uk
0117 300 8276

Letters for publication
reply@sciencefocus.com

Editorial enquiries
editorialenquiries@sciencefocus.com
0117 314 7388

Subscriptions
bbcfocus@buysubscriptions.com
03330 162 113*

Other contacts
sciencefocus.com/contact

WANT MORE ?
FOLLOW SCIENCEFOCUS

FACEBOOK
TWITTER
PINTEREST
GOOGLE+

*Calls from landlines will cost up to 9p per minute. Calls from mobile phones will cost between 3p and 55p per minute but are included in free call packages. Lines are open 8am-6pm weekdays and 9am-1pm Saturday for orders only. If calling from overseas, please call +44 1604 973 721.

BBC Science Focus (ISSN 0966-4270)(USPS 015-160) is published 14 times a year (monthly with a Summer issue in July and a Christmas issue in December) by Immediate Media Company, Bristol, 2nd Floor, Tower House, Fairfax St., Bristol BS1 3BN. Distributed in the US by Circulation Specialists, LLC, 2 Corporate Drive, Suite 945, Shelton, CT 06484-6238. Periodicals postage paid at Shelton, CT and additional mailing offices. POSTMASTER: Send address changes to *BBC Science Focus*, PO Box 37495, Boone, IA 50037-0495.

CONTENTS

25

REGULARS

38

FEATURES

COVER STORY

MORE FOR YOU

Don't forget that *BBC Focus* is also available on all major digital platforms. We have versions for Android, Kindle Fire and Kindle e-reader, as well as an iOS app for the iPad and iPhone.

Can't wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied. **sciencefocus.com**

Special issue

EARTH FROM ABOVE
The latest special edition from the *BBC Focus* team lets you explore the planet as never before, with fascinating photos taken from above the Earth's surface.
buysubscriptions.com/focuscollection

Tunes in the dunes

ORDOS,
NORTHERN CHINA

China's first desert resort, the striking Whistling Dune Bay, sits among sand dunes with a rather special ability: they can sing.

When the wind strikes them, the dunes produce a sound described as a humming, booming, or roaring, which led merchant traveller Marco Polo to think they were possessed by evil spirits. In reality, the noise is caused by an avalanche of sand grains. "The sand grains in the avalanche rub against each other, creating small bursts of sound due to shearing," says Dr Nathalie Vriend, a geophysicist at Cambridge University. "These bursts of sound can amplify due to the dune's unique internal structure, creating the booming sound that can be heard from miles away."

Guests at the hotel are invited to hear the unearthly sounds for themselves by sliding down the dune to produce a rumble reminiscent of an aircraft, or squeezing a handful of sand to make an unusual croaking noise.

PHOTO: EYEVINE

Live and let's fly!

WANNOO,
WESTERN AUSTRALIA

Though commonly seen in a cage at granny's house, wild budgerigars are usually found in small nomadic flocks in the open environments of Australia.

However, during times of drought, their main food sources, grasses, wither as surface temperatures climb to a crippling 65°C. The birds group together to form superflocks of up to several million individuals and embark on a mass search for thousands of kilometres to search for areas with enough water.

"These large flocks occur primarily due to safety in numbers," says Damien Farine, an ornithological research associate at the University of Oxford. "If there are few watering spots, then a predator will just need to sit at one and wait for birds to arrive. One phenomena that happens when groups become very large is that they completely confuse, or dazzle, the predator. By being in very large groups, individual budgies have almost no risk of being predated."

The savvy birds have also been known to shadow kangaroos, who dig for water in damp ground.

PHOTO: ROLAND SEITRE/NATUREPL.COM

THE RPS
ROYAL PHOTOGRAPHIC SOCIETY

INTERNATIONAL IMAGES FOR SCIENCE 2017

Touring the UK from
SEPTEMBER 2017-JULY 2018

rps.org/Science2017

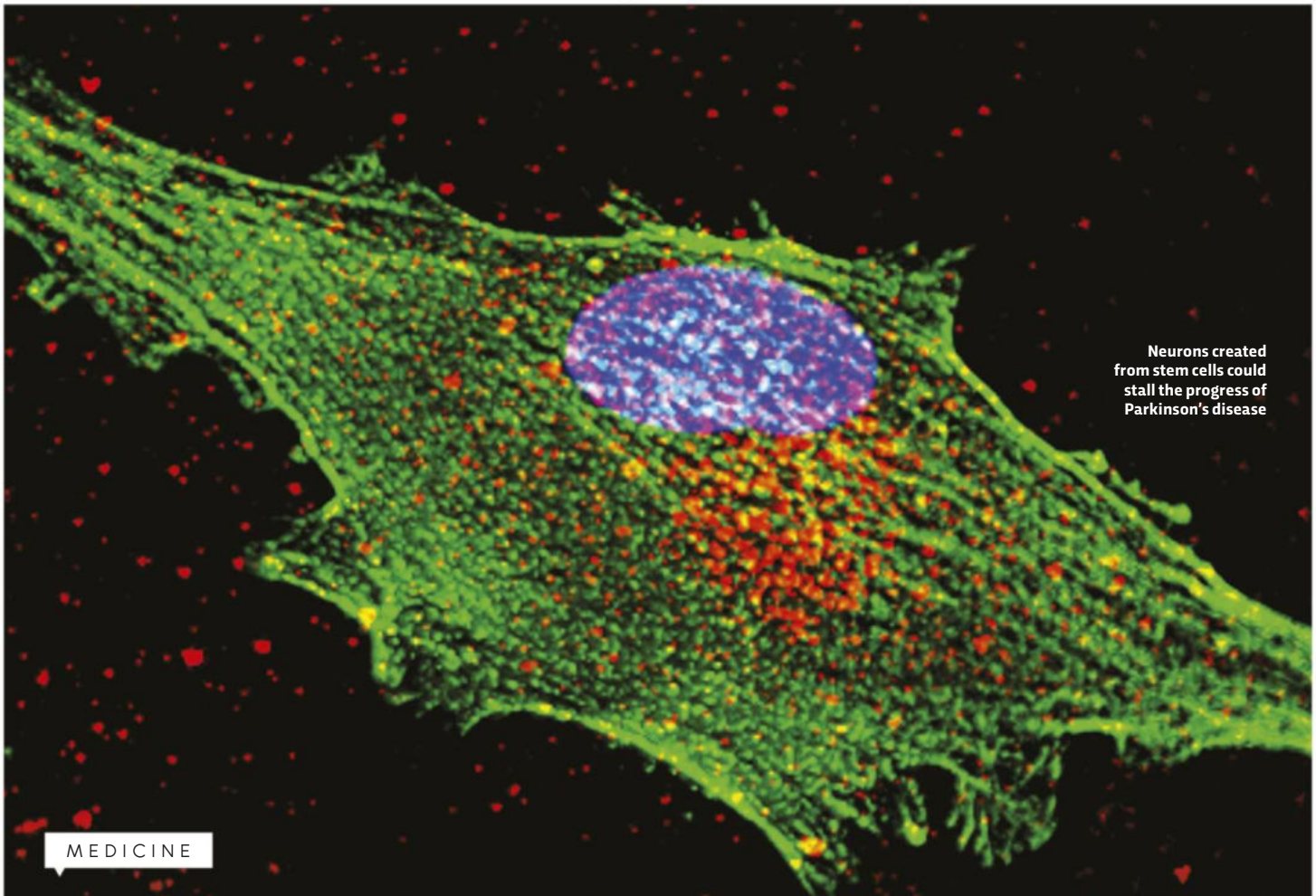
Supported by
SIEMENS

CREDIT: **RICHARD BEECH** Soap Bubble Planet

DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

OCTOBER 2017 | EDITED BY JASON GOODYER



Neurons created from stem cells could stall the progress of Parkinson's disease

MEDICINE

HUMAN STEM CELLS USED TO FIGHT PARKINSON'S DISEASE IN MONKEYS

Clinical trials in humans are now being prepared after Japanese researchers improved the symptoms of Parkinson's disease in monkeys for up to two years

Parkinson's disease is a progressive disorder that attacks a group of nerve cells in the brain known as dopaminergic (DA) neurons. These are responsible for transmitting dopamine – a vitally important chemical used to send signals to the parts of the brain that control movement. As the disease progresses and more neurons are lost, sufferers develop trembling limbs, speech changes and balance problems. There is currently no known cure.

Now, a team at Kyoto University in Japan has successfully used reprogrammed human stem cells to restore brain function in long-tailed macaque monkeys suffering from Parkinson's-like symptoms, and hope to begin clinical trials in humans in as little as a year.

The researchers were able to produce functioning DA neurons using induced pluripotent stem cells (iPS) – cells that are created by 'reprogramming' skin or blood cells into an embryonic state, allowing them to be grown into any kind of human cell.

They created DA neurons from four people without Parkinson's and three people with it, and injected ▸

PHOTO: SCIENCE PHOTO LIBRARY

Parkinson's-like symptoms in macaques have been reduced for up to two years by the new stem cell therapy

them into the brains of seven different monkeys. All of the animals showed a marked improvement in their movements. However, the results depended on the quality of the implanted cells rather than the quantity, which is often the case in stem cell therapies.

"We made DA neurons from different iPS cell lines. Some were made with iPS cells from healthy donors, others were made from Parkinson's disease patients," said researcher Dr Tetsuhiro Kikuchi. "Each animal received cells prepared from a different iPS cell donor. We found the quality of donor cells had a large effect on the DA neuron survival."

The monkeys were given drugs to prevent their immune systems from rejecting the new cells, and were then observed for up to two years without issue.

The team is hopeful that it can begin recruiting patients for this iPS cell-based therapy before the end of next year.

"ALL OF THE ANIMALS SHOWED A MARKED IMPROVEMENT IN THEIR MOVEMENTS"

EXPERT COMMENT

Prof David Dexter

Deputy research director, Parkinson's UK, said:

"Not only did the new cells survive, and were found in later dissections, but they also integrated with the existing neuronal network – functioning like normal dopamine-producing brain cells and allowing gradually improved movement over a 12-month period.

"Although this is promising quality research, and the conclusions are backed up by solid data that comes from a variety of sources, including behavioural, brain scan and histological analysis, there are still major challenges ahead. We need to understand if these new transplanted cells would succumb to the same fate as the original cells that had previously died.

"There are also other types of brain cells that are affected by Parkinson's, and additional work must be done to tackle those symptoms of the condition that are *not* caused by a lack of dopamine."

PHOTOS: FIONA ROGERS/NATUREPL.COM, GETTY

SPACE

BLACK HOLES MAY HAVE HELPED LIGHT UP THE UNIVERSE

Shortly after the Big Bang, the Universe was completely dark. The intense expansion of the fabric of space kicked up so much hot, dense gas that light became completely trapped within it for millions of years. As the Universe expanded, it become more transparent and was gradually lit up by galaxies and stars radiating visible light. Exactly how this happened, however, is something of a mystery.

Now, a team from the University of Iowa think they may have an answer. They suggest that the black holes that dwell at the centre of galaxies caused matter to be flung out so violently that it pierced the cloudy surroundings, allowing light to escape. "It's possible black holes are creating winds that help the radiation from the stars escape," said researcher Dr Philip Kaaret. "Thus, black holes may have helped make the Universe transparent."

Their theory is that the effect is due to black holes acting in a way similar to pirouetting figure skaters, who fold their arms closer to their bodies in order to spin faster. As matter is pulled in towards a black hole by its extreme gravitational pull, the black hole spins faster. This creates an accelerating effect, resulting in a fraction of the matter being flung away from the centre of the black hole.

"As matter falls into a black hole, it starts to spin and the rapid rotation pushes some fraction of the matter out," Kaaret said. "They're producing these strong winds that could be opening an escape route for ultraviolet light. That could be what happened with the early galaxies."

The team proposed the theory after noticing that ultraviolet light coming from Tol 1247-232, a galaxy located 600 million light-years from Earth, was waxing and waning. As stars don't typically show changes in brightness like this, other bodies had to be involved. The team now plans to look for other nearby galaxies that are leaking ultraviolet light, to help corroborate their theory.

Matter being flung from black holes could have helped light up the Universe

IN NUMBERS

665
DAYS

The amount of time spent onboard the International Space Station by American astronaut Peggy Wilson – more than any other woman to date.

20
MILLION

The number of lives that will have been saved by vaccination efforts in the world's poorest countries by 2020, as estimated by a team at the University of North Carolina.

6,000
YEARS

The age of traces of wine found in a terracotta jar in cave in Sicily. It was previously thought that winemaking developed in Italy around 1200 BC.

The outer planets in the TRAPPIST-1 system could be home to vast oceans

SPACE

NEARBY EARTH-SIZED EXOPLANETS MAY HARBOUR HUGE OCEANS

Vast quantities of water may be sloshing around on the surfaces of three potentially habitable planets, offering fresh hope of finding life outside of the Solar System.

In February this year, an international team of astronomers announced the discovery of seven Earth-sized planets orbiting the ultra-cool dwarf star TRAPPIST-1, 40 light-years from Earth. And now, researchers at Switzerland's Observatoire de l'Université de Genève have used data from the Hubble Space Telescope to estimate that the star system's outer planets may harbour large quantities of water, including three that lie within its habitable zone – the distance from a star where the planets' surface temperatures potentially enable them to support life.

This is an important discovery because the presence of liquid water is thought to be essential for the evolution of life. To make their calculations, the researchers took advantage of the fact that ultraviolet radiation from a star causes water molecules on a planet to break up into hydrogen and oxygen and escape through the top of the atmosphere. They say that the four outermost planets in the TRAPPIST-1 system, including three in the habitable zone, don't receive enough UV to have lost significant amounts of water – so most of the water they formed with should, in theory, still be there. However, further studies are required before they can say for sure.

"While our results suggest the outer planets are the best candidates to search for water with the upcoming James Webb Space Telescope," said University of Geneva astronomer Vincent Bourrier, who led the research, "they also highlight the need for theoretical studies and complementary observations at all wavelengths to determine the nature of the TRAPPIST-1 planets and their potential habitability."

PHOTOS: NASA/JPL CALTECH, JOSCHUA KNÜPPE, DEAN R LOMAX

PALAEONTOLOGY

LARGEST PREHISTORIC REPTILE FOUND TO BE PREGNANT

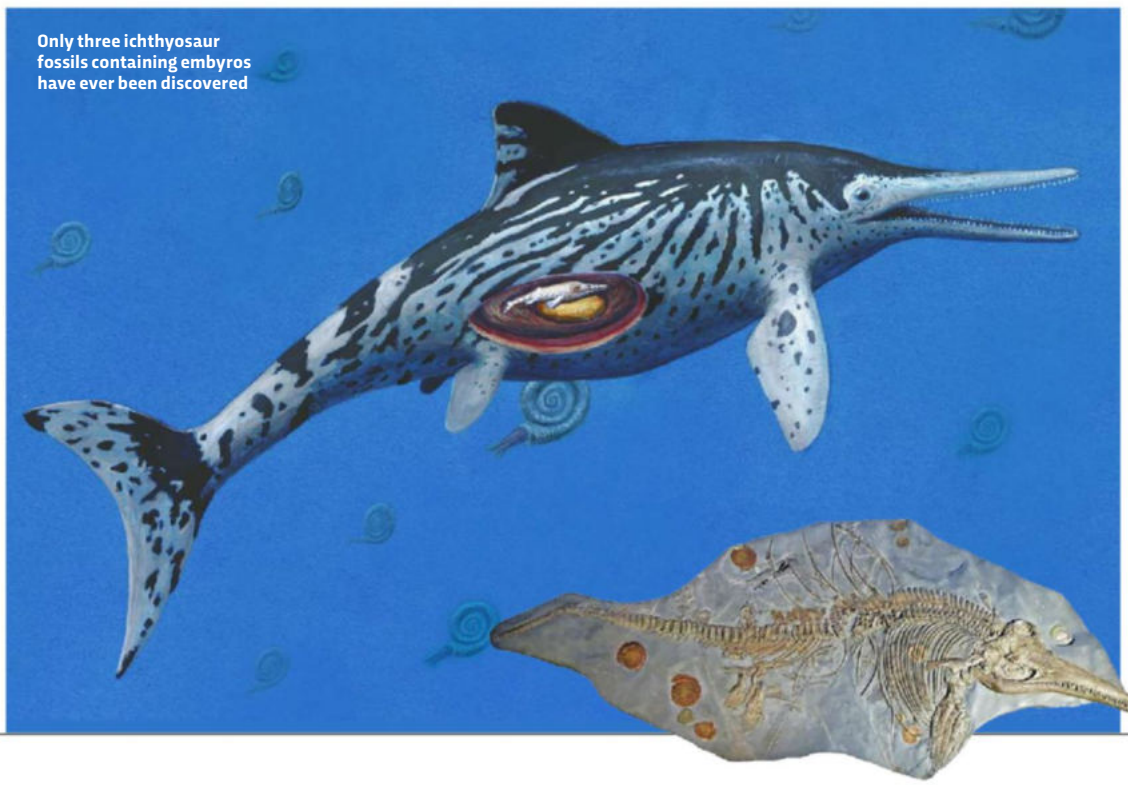
The largest known fossilised specimen of a prehistoric species of aquatic reptile called *Ichthyosaurus somersetensis* has been found in a museum in Germany – and in an unusual twist, it turns out to be that of an expectant mother.

Although sometimes incorrectly referred to as 'swimming dinosaurs', ichthyosaurs were in fact an entirely separate order that evolved from land-based reptiles that had returned to the sea, much as manatees and whales have evolved from previously land-based mammals. They ranged in length from 1m to over 20m.

The *I. somersetensis* fossil in question is of a 3-3.5m adult female. The fossil, which dates back some 200 million years to the Early Jurassic Period, was originally unearthed in the 1990s, but until recently languished in the collection at the Lower Saxony State Museum in Hannover, Germany. That was until it was spotted by palaeontologist Sven Sachs of the Bielefeld Natural History Museum, also in Germany.

Suspecting it could in fact be an *I. somersetensis* specimen, Sachs contacted the University of Manchester's Dean Lomax, who along with his colleague Prof Judy Massare had first described the species. Not only did Sachs' hunch turn out to be correct, the specimen was also found to contain the fossilised embryo of a baby *I. somersetensis*, with a preserved section of vertebrae measuring a mere 7cm long.

"It amazes me that specimens such as this can still be 'rediscovered' in museum collections," said Lomax. "This specimen provides new insights into the size range of the species, but also records only the third known example of an *Ichthyosaurus* with an embryo. That's special."



Only three ichthyosaur fossils containing embyros have ever been discovered

THE DOWNLOAD

FRB 121102

What's that? A Royal Mail tracking number?
It's fast radio burst 121102 – a mysterious electromagnetic signal, originating in a dwarf galaxy three billion light-years away, that was first detected in 2012.

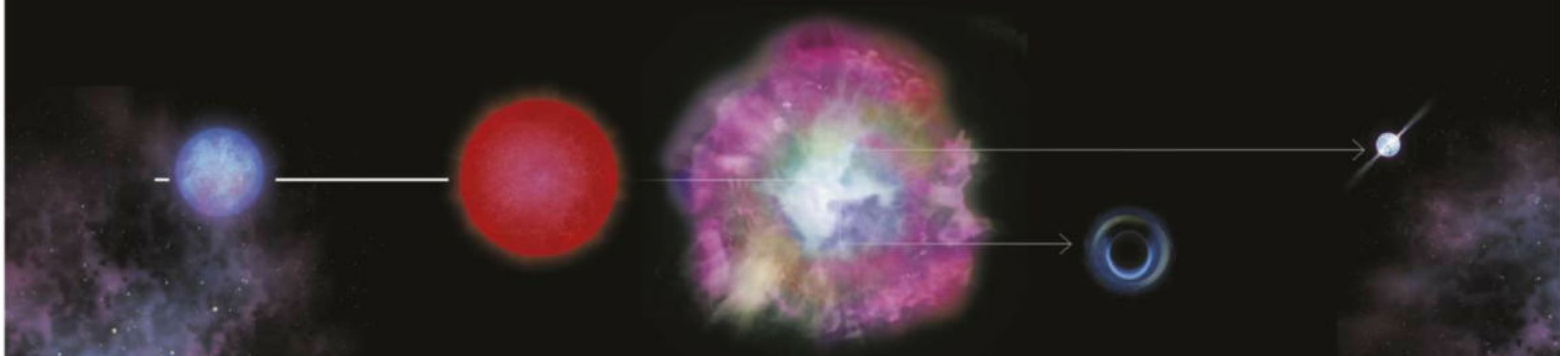
Hang on. What's a fast radio burst?
Fast radio bursts are powerful radio signals, originating in deep space, that last for just a few milliseconds.

Tell me more!
Only a handful of fast radio bursts have ever been detected, and no one has so far figured out exactly what they are. Current theories range from the radiation blasted out as a neutron star is devoured by a black hole, to encoded messages from aliens.

Weird. So why are we talking about it now?
Well, Breakthrough Listen, a $100bn project that was set up to listen for potential signals from extraterrestrial civilisations, has just detected a series of 15 pulses from FRB 121102. If anyone is going to decipher messages sent by little green men, our money is on them, so watch this space... literally!

THE LIFE CYCLE OF HIGH MASS STARS

Stars begin life as clouds of gas and dust, known as nebulae. Material within these nebulae begins to clump together due to the action of gravity, and as the material is drawn closer together it heats up. A star is born when the mass of particles becomes hot enough for nuclear reactions to begin fusing hydrogen into helium within its core.



MAIN SEQUENCE
The first stage of a star's life is known as its 'main sequence'. During this stage the outward forces generated by the burning gases are balanced by the star's gravity. Our own Sun is at this stage.

RED GIANT
Eventually the hydrogen in the core begins to run out. Now, hydrogen begins to fuse into helium in the star's outer layers, causing it to expand. Depending on the star's mass, it becomes a red giant or supergiant.

SUPERNOVA
If the star is large enough, it will continue fusing heavier and heavier elements within its core until it becomes too heavy to withstand its own gravitational force. The core will collapse in a huge supernova explosion that blows away its outer layers.

NEUTRON STAR / BLACK HOLE
If the remaining core is up to a few times the mass of the Sun, it contracts to become a neutron star – an incredibly dense type of star. If it's bigger than that, it contracts further and becomes a black hole.

SPACE

TINY BLACK HOLES MAY HAVE HELPED TO FORGE HEAVY ELEMENTS LIKE GOLD, PLATINUM AND URANIUM

We really are all made of stardust: everything from the nitrogen in our DNA to the oxygen in our blood was made in the interior of stars. Inside a star, hydrogen atoms – the smallest element – are fused together to create helium atoms – the second smallest element – which are then fused together to create heavier elements still. However, even the biggest, most energetic stars are incapable of creating elements heavier than iron.

So where do the heavier elements in the periodic table such as gold, platinum and uranium come from?

Most are believed to have been created in the energetic supernova explosions that occur at the end of a massive star's life, but astronomers at University of California, San Diego have found another possibility: they could be created as tiny black holes chow down on neutron stars, the super-dense cores left behind by exploding stars.

According to the team's calculations, a neutron star could come into contact with a small black hole and become devoured from the inside out by it. The sheer violence of this event would lead to some of the dense neutron star's matter being ejected into space and forming heavy elements.

"Small black holes can invade a neutron star and eat it from the inside," said researcher Prof George Fuller. "In the last milliseconds of the neutron star's demise, the amount of ejected neutron-rich material is sufficient to explain the observed abundances of heavy elements. As the neutron stars are devoured, they spin up and eject cold neutron matter, which decompresses, heats up and makes these elements."

HEALTH

CANCER PATIENTS COULD BE GIVEN FISHY 'AVATARS' TO SPEED UP TUMOUR TREATMENT

It may not look like the next big thing in medicine, but one day this tiny fish could play a key role in saving your life. Portuguese researchers have found that implanting tumours from human patients into the larvae of zebrafish – in effect using them as a medical 'avatar' – could help doctors to find more effective treatments for aggressive cancers.

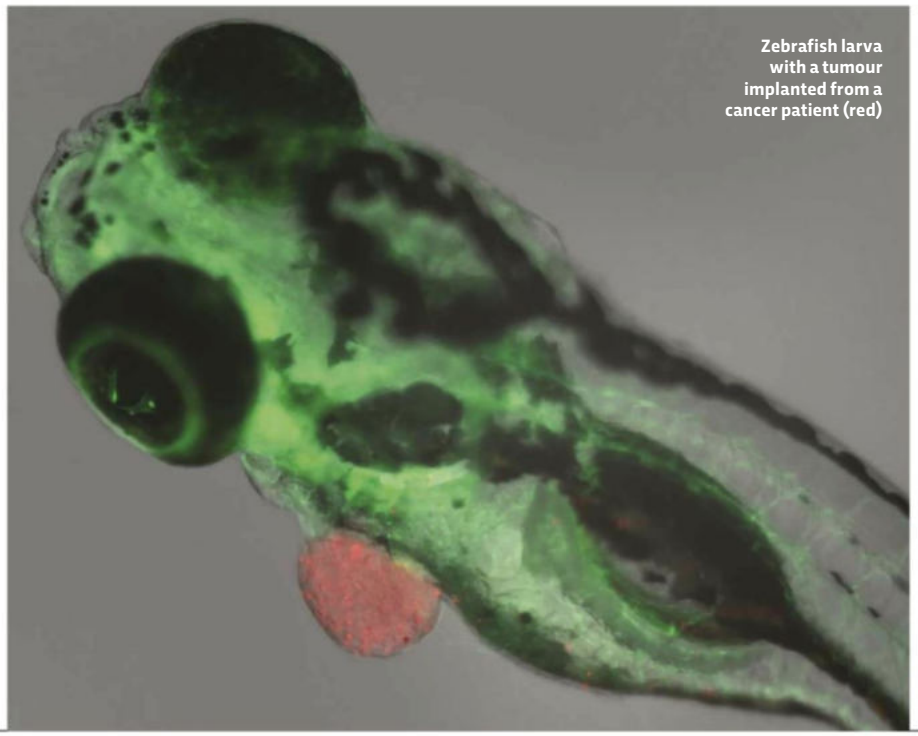
Currently, most chemotherapy treatments are prescribed based on their success in clinical trials involving many patients. The downside to this is that the exact nature of cancer varies significantly across different patients. Tumours respond differently to different drugs and can even change over time, which complicates matters further.

"In some cases, the efficacy rate of chemotherapies can be low, sometimes around 35 per cent," said researcher Dr Miguel Godinho Ferreira. "This means that some patients risk taking inadequate drugs that weaken them, and without a proper test, there is no way to know who will benefit and who won't."

In an attempt to increase these odds, the team transplanted tumour cells from five colorectal cancer patients directly into zebrafish larvae and let them develop for two weeks. They then treated the zebrafish with the same chemotherapy drug that was given to the human patients. The tumours in the zebrafish avatars responded to the treatment in the same way as the human tumours in four out of five cases.

Following this promising start, the team now plan to spend the next two years testing their method in hundreds more patients.

"If all goes well, we will be able to inform oncologists on the result of the different therapies in the avatars. They will always have the final word in terms of deciding which therapy to choose, but they will be able to base their decisions on individual tests," said Ferreira.



Zebrafish larva with a tumour implanted from a cancer patient (red)

THEY DID WHAT?!

JELLYFISH MADE INTO 'CRISPS'

What did they do?
A team of 'gastrophysicists' at the University of Southern Denmark created a new method for drying out jellyfish, turning them into edible 'crisps'.

Why did they do that?
With the world's population growing rapidly, it's imperative we look into alternative sources of food, they say. Jellyfish have been eaten in Asia for thousands of years but the practice has never really taken off in the West, despite the relative abundance of the invertebrates. The researchers believe this may be due to the unusual texture created by the traditional processing procedure. In an attempt to overcome this, they used alcohol solutions to suck the water out of the jellyfish, leaving them similar in texture to potato crisps.

What did they find?
The researchers say the mouth feel and the aesthetic appearance of the jellyfish have "gastronomic potential" and that they actually taste pretty good. Hmm... we'll stick to ready salted for the time being.

ENGINEERING

"We plan on using microbots as tools to manipulate cells and measure their properties"

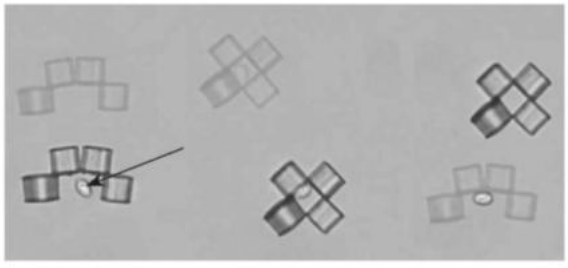
Folding robots controlled by magnetic fields can be used to study microscopic objects such as cells. Prof Orlin Velev *of North Carolina State University explains how they work*

What are your microbots made of?
We started with so-called 'active particles' that can perform simple tasks such as pushing and penetrating objects. Now we're studying complex self-folding shapes, such as cubes. Our aim is to make interesting structures for use in future technologies.

Our particles are small cubes with one side coated with metal. They become magnetic when we apply magnetic fields and are able to move and change shape.

How do you build a bot?
Our colleagues from Duke University make the cubes and metallise them, then we perform the research in my laboratory. We put a suspension of cubes in water into a small chamber surrounded by electromagnets, then observe their behaviour with a microscope. Originally they're dispersed around, but when we turn on the magnetic field, they begin assembling into different sequences. Some sequences can fold like origami and repeatedly perform opening and closing motions, which we used to demonstrate the microbot principle.

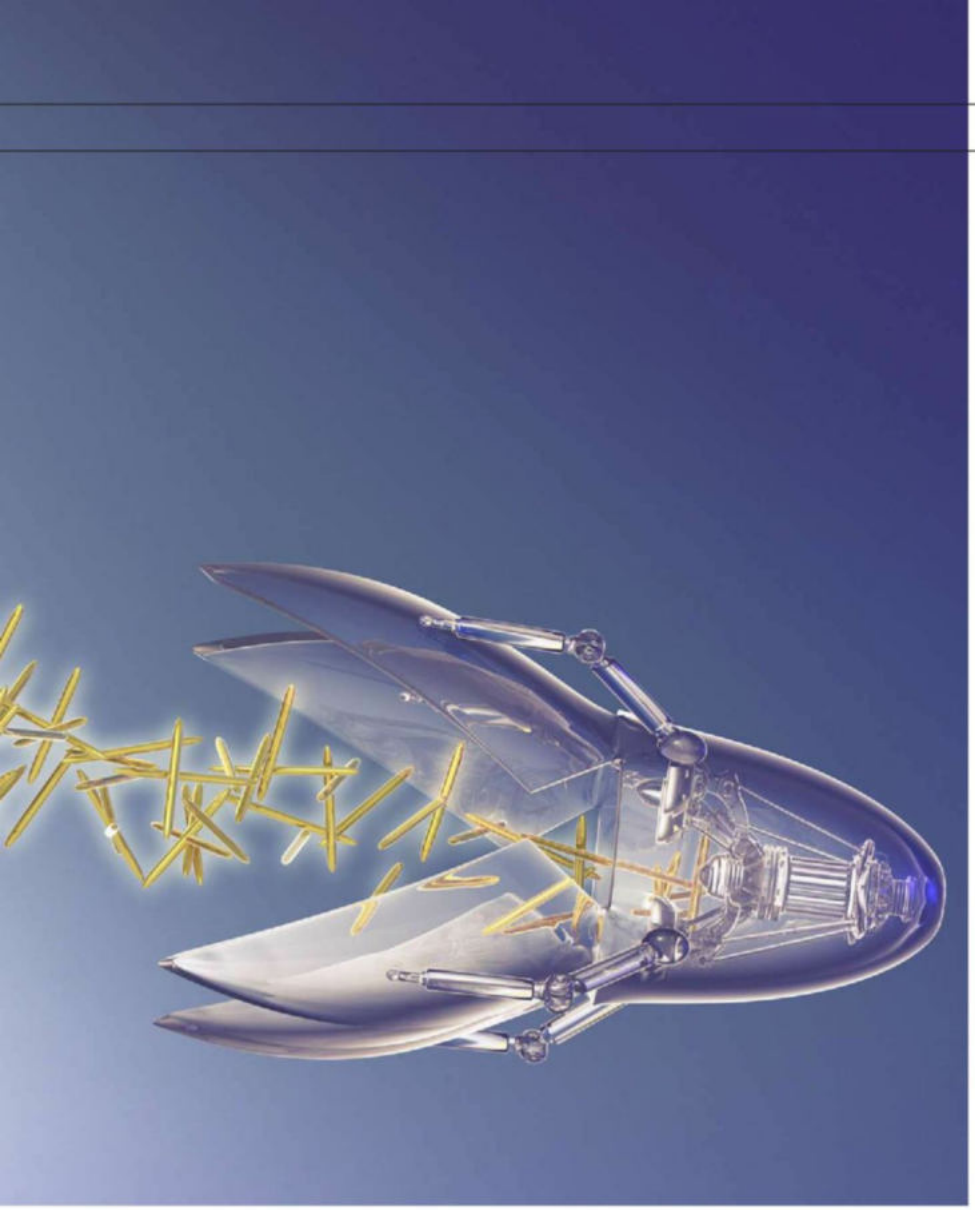
BELOW: **Four cubes can be arranged in a box-like cluster, then opened and closed like Pac-Man to capture a yeast cell (marked by arrow)**



How do magnets control movement?
When we turn the field off, cubes preserve their magnetic properties and interact with each other. Every time we turn the field on, they adopt one configuration; when we turn it off, they adopt another. So we can reversibly fold and unfold them. In addition, we can control field strength and 'gradient' [in which direction the field acts] and this is what distinguishes our microbot assemblies: we can move them around and *independently* make them open and close.

You can actually see the microbot in operation and can use it to catch cells. When four cubes are set up in a box-like cluster, the configuration stores magnetic energy. By turning the magnetic field on, it opens; when we turn the field off, it closes. It behaves like a tiny Pac-Man. We made it 'swim' towards a yeast cell, before closing around it. We use

PHOTOS: GETTY, PROFESSOR ORLIN D VELEV/NC STATE UNIVERSITY ILLUSTRATIONS: DAN BRIGHT



ABOVE: **Microbots could one day be used to target cancer cells, like in this artist's impression**

magnetic fields again to drag the cell to a new position and release it.

Why are microbots useful?

We plan on using microbots as tools to manipulate other types of cells, and to measure their properties. We are initiating a project to investigate cells and vesicles – small lipid-based structures, similar to cells, which are used for drug delivery.

One of the next applications is to characterise materials. Say you want to distinguish a cancer cell from a regular cell: you can use fluorescent dye or you can use the microbot to pinch the cells and see their mechanical properties, which may differ. So now we have a microscopic device that can be used in sorting and testing different cells in a culture. We're not going to address treatment of cancer, at least not at this stage. The most exciting thing is that there's still so much we can learn about how to make particles that have unique features we can use.

You can watch a folding microbot in action at **bit.ly/microbot_origami**

SLEEPYHEADS

Got an exam but don't feel like revising? Sleep on it. Paris-based psychologists have found we can learn while getting forty winks. Twenty test subjects could remember patterns of sounds played to them during REM sleep.

DANCERS

Want to stay sharp and spritely in old age? Better put on your dancing shoes. German researchers have found strutting your stuff is the most effective activity for slowing down age-related mental and physical decline.

GOOD MONTH

BAD MONTH

WINE DRINKERS

Sacré bleu! French vineyards are experiencing their poorest harvest since 1945, thanks to a chilly April. The Bordeaux region is expected to be hit the hardest, producing 40 per cent less plonk.

BINGE WATCHERS

With TV series available on demand, it's all too tempting to partake in marathon viewing sessions. But a Belgian study has found binge watching can lead to fatigue and insomnia due to the increased mental alertness triggered by the shows' drama and excitement.

This tiny device can turn skin cells into the building blocks of vital organs

MEDICINE

NANOCHIP COULD HEAL INJURIES WITH "ONE TOUCH"

Researchers at the Ohio State University have designed a tiny device that genetically reprogrammes skin cells. It's hoped it could be used to repair injured tissue, including organs, blood vessels and nerve cells.

Dubbed 'tissue nanotransfection' (TNT), the new technique uses a coin-sized device that is placed on the patient's skin. The device is then zapped with a small electric charge, triggering it to deliver a package of specially engineered genes to the target skin cells, transforming them into different types of cells entirely. "With this technology, we can convert skin cells into elements of any organ with just one touch," said researcher Dr Chandan Sen. "This process takes less than a second and is completely non-invasive, and then you're off. The chip does not stay with you, and the reprogramming of the cell starts. Our technology keeps the cells in the body under immune surveillance, so immune suppression is not necessary."

In one experiment, the team successfully reprogrammed skin cells to replace blood vessels in a mouse with a badly injured leg. Just one week after treatment, active blood vessels began to grow in the mouse's damaged leg, and by the second week its limb was saved. In another experiment, the chip was used to create nerve cells that were then injected into mice to help them recover from brain injuries caused by stroke. Clinical trials in humans will start next year.

PHOTOS: OHIO STATE UNIVERSITY WEXNER MEDICAL CENTER, GETTY, OREGON STATE UNIVERSITY

PALAEONTOLOGY

100-MILLION-YEAR-OLD FLOWERS FOUND PERFECTLY PRESERVED IN AMBER

Millions of years ago, in a pine forest in Myanmar, a group of tiny flowers fell tumbling to the ground. Upon falling, they landed in a patch of tree resin, which later fossilised into crystal clear amber – keeping them in perfect condition until they were discovered by a team at Oregon State University earlier this year.

Dubbed *Tropidogyne pentaptera* thanks to their distinctive shape, ('penta' means five and 'pteron' means wing), the flowers belong to a previously undiscovered species of tree and date back to the Cretaceous Period, making them around 100 million years old.

The flowers lack petals but have pronounced sepals – green leaf-like structures that protect the flower while it's in bud – and measure between 3.4 and 5mm in diameter.

"The amber preserved the floral parts so well that they look like they were just picked from the garden," said researcher Prof George Poinar Jr. "Passing dinosaurs may have knocked the branches that dropped the flowers into resin deposits on the bark of an araucaria tree, which is thought to have produced the resin that fossilised into the amber."

The flowers have been placed in the family *Cunoniaceae*, a group of trees still common to the Southern Hemisphere, and are believed to have belonged to a rainforest tree. The closest living relative to the prehistoric tree is likely to be the coachwood tree found in Australia. This also has no petals, only sepals, can grow to heights greater than 35m, lives for centuries and produces an attractive hardwood that is used for flooring and furniture.

This little flower is an incredible 100 million years old

SPACE TRAVEL

HUMAN WASTE COULD BE THE KEY TO LONG-DISTANCE SPACE TRAVEL

If we are ever going to have any chance of making it to Mars, astronauts are going to have to make the best use of every possible resource – even their own urine. Crew on-board the International Space Station already have a system in place that creates drinking water from urine. But now, a team at Clemson University in South Carolina has taken things a step further by making a system that can create plastics from human urine and exhaled breath.

"If astronauts are going to make journeys that span several years, we'll need to find a way to reuse and recycle everything they bring with them," said researcher David Blenner. "Having a biological system that astronauts can awaken from a dormant state to start producing what they need, when they need it, is the motivation for our project."

The system takes the nitrogen from urine and carbon dioxide from exhaled breath and uses them to feed a type of yeast, *Yarrowia lipolytica*, that has been genetically engineered to churn out monomers – a special type of molecule that can be strung together to form plastic polymers. The plastic, in this case polyester, can then be 3D printed to make tools and replacement parts as needed.

THINGS WE LEARNED THIS MONTH

BIRDS USE THEIR SENSE OF SMELL TO NAVIGATE

A team at Oxford University temporarily blocked the sense of smell of a group of Scopoli's shearwaters before tracking their movements. The birds were able to navigate as normal across land but became confused when flying over the ocean, suggesting they use a map of smells when lacking visual clues.

WHISKEY TASTES BETTER WITH WATER

Diluting your dram with water can increase the density of flavour compounds on the drink's surface, making it a tastier tipple, Swedish researchers say.

CLIMATE CHANGE IS TURNING BROWN BEARS VEGETARIAN

A group of bears on Alaska's Kodiak Island have switched from eating spawning salmon to red elderberries, thanks to warmer summers causing the fruit to ripen earlier. They choose the berries as they require less energy to acquire.

THERE COULD BE SNOW ON MARS

According to calculations by researchers from the University Pierre and Marie Curie in France, the Red Planet experiences mini snow blizzards.

ARCHAEOLOGY

ANCIENT CLAY TABLET SHOWS BABYLONIANS USED TRIGONOMETRY CENTURIES BEFORE GREEKS

At 13 x 9cm in size, the Plimpton 322 tablet is about the size of a large smartphone

Trigonometry, the mathematics of the relationships between the lengths and angles of triangles, has long been thought to have started in earnest with the work of Hipparchus, a Greek astronomer who lived around 100 BC.

Now, researchers at the University of New South Wales have found evidence of trigonometry inscribed in cuneiform script (an early system of writing) on a Babylonian clay tablet that pre-dates Hipparchus by more than 1,000 years. They believe it may have been used by ancient engineers to calculate how to construct palaces, temples and canals.

Known as Plimpton 322, the tablet was discovered in the early 1900s in what is now southern Iraq by American archaeologist Edgar Banks – a man who's said to be the inspiration behind fictional character Indiana Jones. The tablet is thought to have been made in the ancient Sumerian city of Larsa in around 1800 BC.

"The huge mystery, until now, was its purpose – why the ancient scribes carried out the complex task of generating and sorting the numbers on the tablet," said researcher Dr Daniel Mansfield. "Our research reveals that Plimpton 322 describes the shapes of right-angled triangles using a novel kind of trigonometry based on ratios, not angles and circles [as found in modern trigonometry]. It is a fascinating mathematical work that demonstrates undoubted genius."

The 15 rows on the tablet describe a sequence of triangles that make up a trigonometric table – a chart detailing the relationship between the three sides of a right-angled triangle.

"A treasure-trove of Babylonian tablets exists, but only a fraction of them have been studied yet," said researcher Norman Wildberger. "The mathematical world is only waking up to the fact that this ancient but very sophisticated mathematical culture has much to teach us."

PHOTO: UNSW/ANDREW KELLY

HOW UBER DRIVERS LEARNT TO BEAT THE SYSTEM

Why management by numbers is the enemy of productivity

Pretty much everyone in management these days seems to think success comes from having plenty of the stuff scientists treasure above all else: data.

From sales performance to customer satisfaction, there's not much that doesn't get quantified these days. My former colleagues on Fleet Street recently found sensors under their desks, which management said was for monitoring "energy efficiency".

There's even one of those clever-dick MBA maxims to explain it all: "If you can't measure it, you can't manage it". That's debatable, but as some Uber drivers have found, there's definitely a flip side: if you can measure it, you can game it.

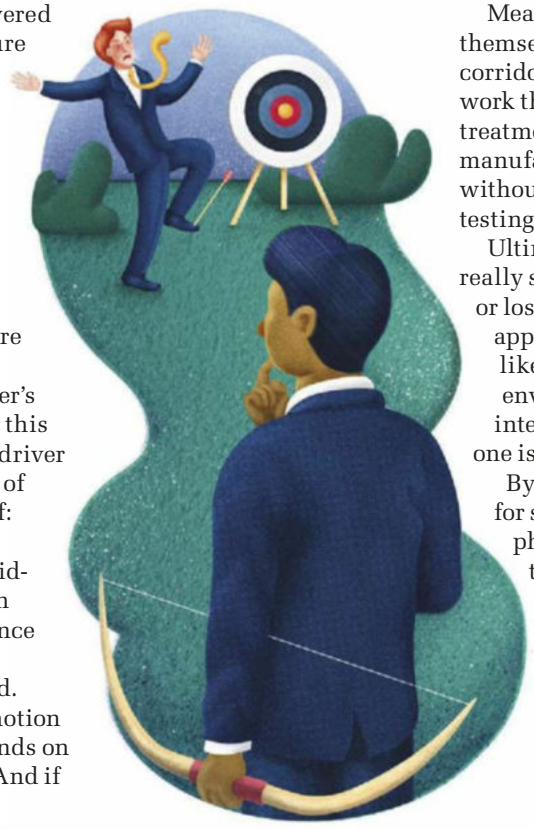
To keep tabs on their drivers, the ride-hailing company uses software to track their whereabouts – or 'manage' them. But some of the drivers have found ways of gaming Uber's system to boost their income.

Researchers at the University of Warwick and the University of New York have discovered that some drivers work together to ensure they're unavailable at certain times. That tricks Uber's billing algorithm so it switches to 'surge pricing', where the scarcity of drivers leads to passengers being charged more. The drivers then log back on, and get a bigger cut.

The researchers found that many drivers are happy to game Uber's tracking system because they feel they're working for an algorithm, rather than a company. I wouldn't be surprised if Uber's top brass are now planning to 'manage' this issue with an algorithm that measures driver resentment. If so, they should be aware of another problem with quantifying stuff: Goodhart's Law. Identified by an eponymous British economist in the mid-1970s, the law states that when you turn something measurable into a performance target, it ceases to be any good.

The reason is that people aren't stupid. Once they twig that their income, promotion or indeed continued employment depends on meeting a target, they'll focus on that. And if they can't meet it, they'll game the system instead.

"WHEN YOU TURN SOMETHING MEASURABLE INTO A PERFORMANCE TARGET, IT CEASES TO BE ANY GOOD"



That seldom ends well. During the Vietnam War, US commanders tried to measure success by 'body counts' of enemy casualties. This practice was encouraged by the defense secretary Robert McNamara, who had spent decades in senior management in the car industry. But faced with a wily enemy which routinely vanished back into the jungle along with its dead, US field commanders often invented numbers to convince McNamara and co they were winning. And we know how that panned out.

Over 40 years later, Goodhart's Law can be seen in every walk of life. League tables are supposed to show which schools are providing a decent education. Yet as Ofsted's new chief inspector recently pointed out, in reality the tables encourage schools to play tricks, like entering pupils for non-academic qualifications, which boost rankings, but do zip for social mobility.

Meanwhile, NHS patients have found themselves kept in ambulances or wheeled into corridors for 'observation' as hospital managers work the system for achieving target times for treatment. And of course some diesel car manufacturers struggling to meet emission targets without trashing performance took to fiddling the testing procedure instead.

Ultimately, targets are okay when applied to really simple stuff like winning the Premiership or losing weight. The trouble starts when they're applied to complex, multi-dimensional issues, like the quality of education, hospital care, or environmental impact. Each has so many interacting components that focusing on just one is sure to cause trouble somewhere else.

By hoping data can do for them what it does for science, managers are committing what philosophers call a category error: believing that something which applies in one domain does so elsewhere.

But don't expect that argument to wash with management. They'll just blink and demand evidence – in the form of data.

Robert Matthews is visiting professor of science at Aston University, Birmingham.

ILLUSTRATION: DANIEL BRIGHT

MADE IN THE UK

CHORD

Chord Electronics Ltd.

Hugo 2

Transportable DAC/headphone amplifier

WHAT HI-FI?

★ Stars of CES | 2017 ★

avforums BEST BUY AWARD 2017 Chord Electronics Hugo 2

THE LEGEND, REMASTERED

SUPERCHARGE YOUR LISTENING EXPERIENCE

AVAILABLE NOW

visit **chordelectronics.co.uk** for more information and to locate your nearest dealer

/chordelectronics

@chordaudio

/chordelectronics

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

OCTOBER 2017 EDITED BY RUSSELL DEEKS

EAT MY DUST

Meet the supercar of tomorrow: the HIPERCAR (no, that's not a typo – it stands for HIgh PERformance CArbon Reduction). It's been designed by Ariel, the British manufacturers behind the Ariel Atom, who say that when the car rolls out of the factory in 2020 it'll be the most advanced, and fastest-accelerating roadcar ever made.

The car is essentially a testbed where Ariel, and two other technology partners, will try to make electric cars go faster and further than ever before. The HIPERCAR will manage 0-60mph an eye-watering 2.4 secs, and will hit 100mph in 3.8 secs (that's over two seconds nippier than the McLaren P1), before maxing out at a top speed of 160mph. In fact, the speed and power are so monumental that simulations suggest the vehicle could end up wheel-spinning at 100mph, so Ariel is looking at placing fans underneath the car to 'suck' it onto the road to give it traction.

To give it a bigger range, Ariel and its partners have developed a revolutionary 35kW micro-turbine range extender. When the car runs out of battery this incredibly small, petrol-powered motor will generate extra electricity. The team behind the car hopes the affordability and size of their range extender will mean this technology will find its way into more electric cars, making them more feasible to the general public.

1

2

3

4

5

WANTED

1 JELLY BONE

Want a cheap and lightweight phone to take on your travels in place of your smartphone? The tiny, slimline Jelly runs on Android 7.0 Nougat, and packs in 4G reception, up to 2GB of RAM, a 2.45-inch screen, dual cameras, Wi-Fi, Bluetooth and GPS.

Unihertz Jelly

From $79 (£60 approx), unihertz.com

2 MEASURING UP

This smart 'tape measure' has two laser sensors and a roller for taking measurements. It relays that data to a mixed reality space-planning app on your iOS/Android device, so you can work out what goes where before you start humping sofas around.

Plott Cubit

$99 (£76 approx), letsplott.com/cubit

3 BLOWING IN THE WYND

Billed as "the smartest air purifier ever", Wynd is a portable device that will cleanse the air around you from dust, smoke, allergens and particles, while sending air quality data to your smartphone so you can monitor exposure to hazardous substances.

Wynd

£199, hellowynd.com

4 ROBOT SUITCASE

The fully autonomous Travelmate robotic suitcase will happily roll along behind you through the airport (no more lugging bags for you!). It navigates crowds, and comes with a built-in weighing scale, LED lights, fingerprint security and GPS tracking.

Travelmate

From $499 (£385 approx), travelmaterobotics.com

5 HEAT IT

Buzzfeed's first foray into hardware is a Bluetooth-enabled hotplate that links to their Tasty app, enabling even those who've been known to burn a tin of beans to cook over 1,700 dishes to perfection. Perfect for students heading off to uni!

Buzzfeed Tasty One Top

$149 (£115 approx), tastyonetop.com

6 GIVE TAPES THE ELBOW

If you've got a box of old cassettes but nothing to play them on, this compact tape player could be just the ticket. It's just a concept for now – and we're not expecting premier sound quality – but we can see it going down a storm with hipsters.

Elbow

£TBC, elbow.co.nf

6

FEAST FOR THE EYES

Television expert **Verity Burns** takes a look at which of the latest 4K sets are worth their salt

If you're in the market for a new TV and can afford to splurge on the best, we've picked three from the leading flagship ranges that balance out price and performance most convincingly. Two are OLED (organic light-emitting diode) displays – a newer technology that's doesn't need a backlight, and so provides more accurate colours – while Samsung has been perfecting the traditional LCD, which is typically brighter and more efficient. Both are capable of superb performances, but which comes out on top?

SONY BRAVIA KD-55A1

If you want the best TV picture going this year, the Sony Bravia A1 has to be in with a shot.

It's Sony's first stab at 4K OLED technology, but you'd never know it, thanks to a supremely sharp, detailed picture and natural colour palette. It boasts all the inky blacks and outstanding contrast that OLED technology offers, meaning it's great with HDR material, and motion handling is impressive too.

Even its sound is innovative, produced by (discreetly) vibrating the screen to create a solid, direct performance that'll delay the need for a soundbar.

One thing to consider – its standless design looks impressive but is not the easiest to accommodate. You'll need a lengthy TV rack to fit the full width of the screen. **10/10**

£3,000, sony.co.uk

SAMSUNG QE55Q7F

While OLED has been the big TV news of 2017, Samsung is sticking with trusty LCD, re-branding its flagship range to the ever-so-OLED-sounding QLED, in the process.

One of the biggest benefits here is the brightness of the screen – its LED backlighting puts more punch behind colours, and makes whites more impactful. Even though its blacks don't go as deep as OLED, the brilliance of its highlights makes up for it.

This means 4K HDR content looks superb, with more vibrancy than you'll see on OLED. It's not as natural, but it's warmer and more dynamic.

It doesn't scrimp on detail either, with a sharp, clean picture that's hard to fault. Viewing angles are a little tighter than OLED though, so the closer you sit to centre, the better. **9/10**

£2,000, samsung.com

LG OLED55B7

LG knows how to do OLED. It stuck with the technology when no one else did, and has since supplied panels to its competitors who want in on the action. That's presumably how it's able to offer a television this good for £1,000 less than Sony's Bravia KD-55A1.

The performance compared to the A1 is undeniably close, offering a picture just as crisp, with equally impressive contrast. Its colour handling isn't quite as insightful, nor its motion as precise, but it's kinder with standard-definition content and upscales with less noise.

As for sound, this telly won't let you down, thanks to a spacious and dynamic performance that belies its slim design.

You're more future-proofed for HDR here too, with the B7 supporting HDR10, Dolby Vision and HLG out of the box. **10/10**

£2,000, lg.com/uk

TV SPECIFICATIONS

TV	Sony Bravia KD-55A1	Samsung QE55Q7F	LG OLED55B7
SCREEN TYPE	4K HDR OLED	4K HDR LCD	4K HDR OLED
SCREEN SIZE	55 inch	55 inch	55 inch
DIMENSIONS (H x W x D)	711 x 1,228 x 339mm	789 x 1,226 x 304mm	764 x 1,229 x 254mm
HDMI INPUTS	4	4	4
HDR FORMATS SUPPORTED	HDR10 (HLG & Dolby Vision via firmware update)	HDR10, HLG	HDR10, HLG, Advanced HDR by Technicolor, Dolby Vision

VERDICT

If you're having trouble picking a winner, you're not alone. This talented trio has to be one of the most competent line-ups of top-range tellies that we've seen in a while – choose any one of them and you'll most likely be very happy indeed.

For the brightest, most vibrant picture, the Samsung Q7 is the one to beat. It's a different balance from the more natural-looking OLEDs, but no less compelling – just be sure to bag the centre seat on the sofa to enjoy the best performance.

That's less of a worry with the two OLED sets, which are closer in ability than their prices would suggest. While the Sony A1 does pip the LG B7 for overall picture and sound quality, the B7's much cheaper price tag is hard to ignore. The smart money is best spent here.

WINNER: LG OLED55B7

Volocopter is fully electric and has been cleverly engineered to minimise noise

TRANSPORT

AUTONOMOUS HELICOPTER TAXIS COULD BE TAKING OFF

Volocopter's plans to build a fleet of autonomous helicopters for use as taxis have been covered in this magazine before. But the German company's ambitions were recently given something of a lift in the form of $30m of investment from manufacturer Daimler.

The lower half of Volocopter's heli-taxi looks like a standard helicopter, with two landing skids, a long, narrow tail and a cockpit that can house two people. Where a standard helicopter would have rotors on the roof and tail, however, the Volocopter has instead a large, circular frame on which are mounted no fewer than 18 individual rotors. This innovative design is said to make the machine much more stable in the air than traditional helicopters.

The Volocopter made its first manned flight in 2016, but with help from Daimler's investment the company now plans to develop an autonomous version. It hopes to start trials in Dubai this year, with a view to a fleet of the vehicles being used for personal transport in and around the city within a few years.

And if that all sounds like a far-fetched proposition, just bear in mind that many people said the same thing when engineer Gottlieb Daimler built the first motorcycle in 1885…

ENERGY

IKEA IS SELLING SOLAR STORAGE BATTERIES

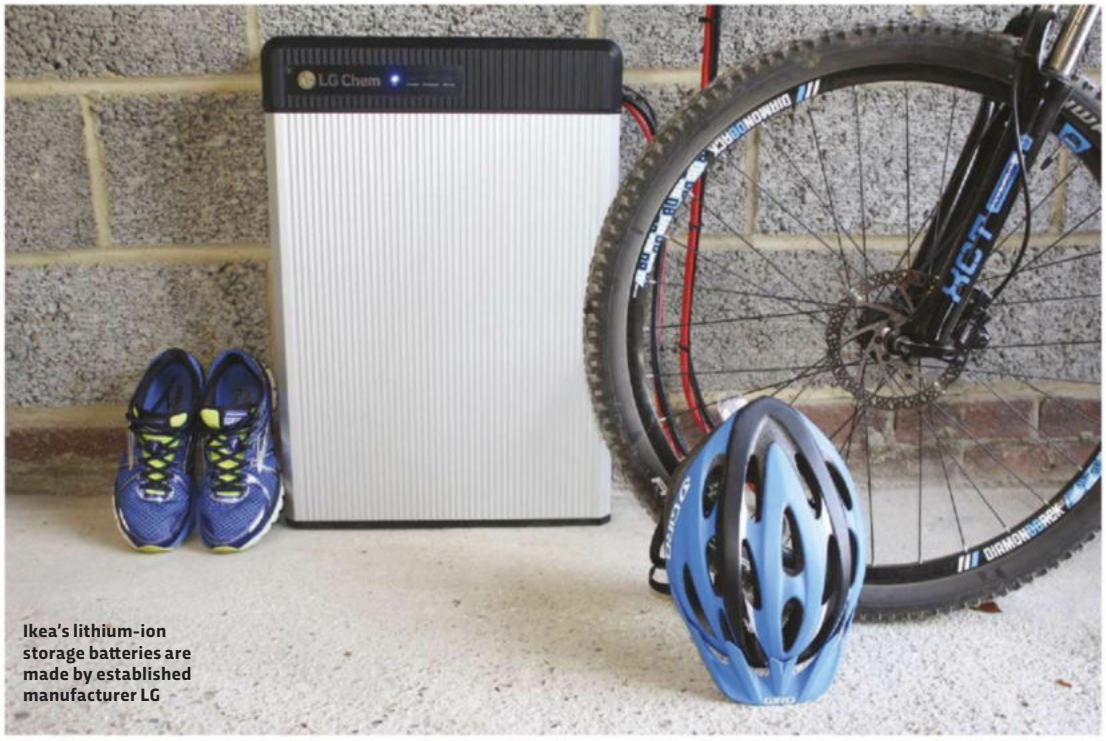
With more and more homes sporting solar panels on their roofs, furniture giant Ikea is now selling a large domestic battery that will enable you to store any excess power generated for future use.

Ikea started selling solar panels in 2013 but stepped away from the market when the UK government announced that it was scrapping solar subsidies. Last year it returned to the solar fray, working in association with Solarcentury, which is one of the biggest and longest-established providers of solar equipment in the UK.

Until now, however, anyone who installed Ikea/Solarcentury's rooftop panels had no option but to sell any excess power generated to the National Grid.

Now, the two companies have taken a leaf out of Tesla's book and developed a large domestic battery – similar to Tesla's Powerwall – that can store that power for use at a later date, rather than forcing users to buy electricity back from the National Grid on less sunny days.

Anything that reduces our reliance on power generated from non-renewable sources has to be a good thing, but the stumbling block for most people is going to be the price. A basic Ikea/Solarcentury system consisting of a battery and a couple of solar panels will cost around £6,500, while the battery alone (if you want to add one to an existing power generation system) will cost in the region of £5,000.



Ikea's lithium-ion storage batteries are made by established manufacturer LG

TECH BYTES

ROBOTS GOT SEOUL

Visitors to Incheon Airport in Seoul, South Korea will soon be greeted by robots made by LG. The Airport Guide Robot will offer directions and tourist advice in Japanese, Chinese, English and Korean, while Airport Cleaning Robots will keep the place looking smart.

DRONE LAWS

UK owners of unmanned aerial vehicles will have to register all drones over 250g with the Department for Transport and undertake a safety awareness test, according to new government plans. The move comes after several incidents in which drones caused safety problems at airports.

DRIVERLESS CARS? NO THANKS!

India's transport and highways minister Nitin Gadkari has announced plans to ban autonomous vehicles in the country, in a bid to protect the jobs of India's bus, taxi and goods vehicle drivers.

SECURITY

A US COMPANY IS MICROCHIPPING ITS STAFF

Three Square Market, a Wisconsin-based company that makes vending machines, has become the first US business to microchip its employees.

Three Square Market – also known as Three Two Market or 32M – has teamed up with Swedish firm Biohax to offer its staff the opportunity to have a computer chip, roughly the size and shape of a grain of rice, embedded below the skin in the fleshy bit between their thumb and forefinger. Once the chip is in place, it will operate in much the same manner as the swipe cards already used in many offices for door entry systems or printer access. Biohax has previously worked with Swedish firm Epicenter, to offer similar microchips to its staff. In both instances, the 'chipping' has been entirely voluntary.

The move has understandably raised concerns among privacy campaigners, but Three Square Market stresses that the chips are not GPS-enabled and cannot, therefore, be used to track a user's movements. As the chip also has the capability to be used as a cashless payment system, it's believed the company may simply be using its employees as 'guinea pigs' in the development of new payment mechanisms to be used in its commercial products.

Indeed, Three Square Market's CEO has said he expects such a system to one day be used widely in the retail and transport sectors. How well the public will respond to being told they need to have a microchip implanted in their skin before they can catch a bus remains, of course, to be seen…

The chip is inserted using a syringe, and feels similar to having an injection

The microchips allow employees to access the building, without using ID cards

The majority of Three Square Market's employees have signed up to get the $300 chips inserted

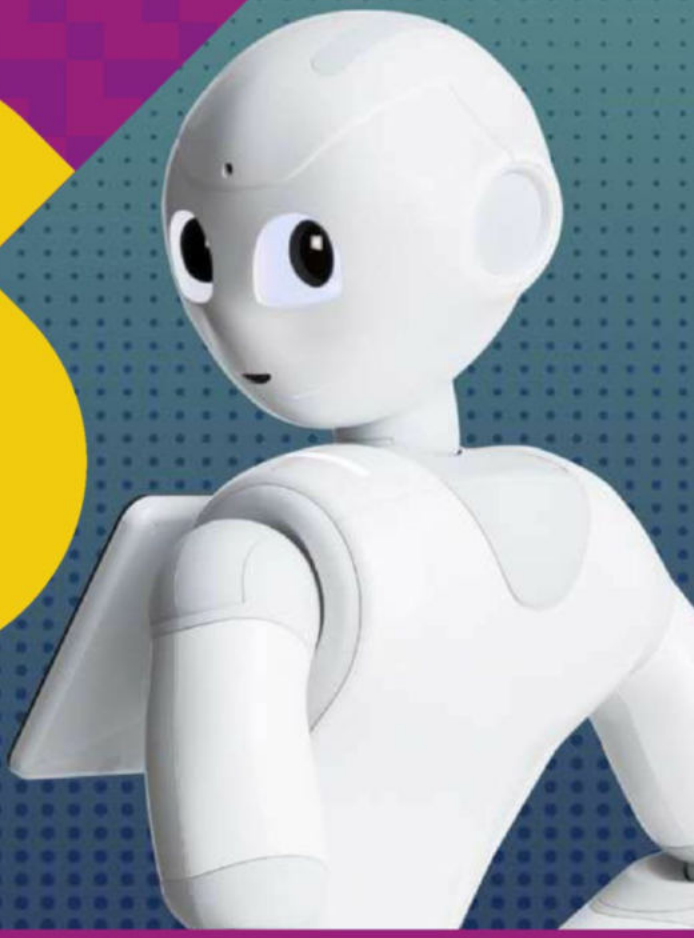
The chips also enable staff to access their computers

PHOTOS: THREE SQUARE MARKET

Manchester Science Festival

Thursday 19 October – Sunday 29 October

17



Headliners include major exhibition Robots and incredible spider's web inspired installation Tape.

Tickets available online from 4 September.

Part [laboratory playground

#msf17 / @mcrscifest
manchestersciencefestival.com

Produced by MUSEUM OF SCIENCE & INDUSTRY

Lead Educational Sponsor University of Salford MANCHESTER

Major Sponsors Waters THE SCIENCE OF WHAT'S POSSIBLE. electricity north west Bringing energy to your door

Media Partner FOCUS MAGAZINE

Image: Soft Robotics

REPLY

Your opinions on science, technology and BBC Focus

reply@sciencefocus.com
BBC Focus, Tower House, Fairfax Street, Bristol, BS1 3BN
@sciencefocus
www.facebook.com/sciencefocus

MESSAGE OF THE MONTH

WHY TAKE CHANCES?

I wanted to respond to Matt Ridley's 'Opinion' piece (August, p38) on the availability of world resources. One issue Matt failed to discuss was the effect that dire warnings about a lack of resources have had in terms of reducing the wasteful use of those resources. Matt appears to assume that warnings about oil running out in the 1970s were just plain wrong, and everything has proceeded normally. However, it was around this time that efforts on renewable energy sources were started, and this has delivered, today, some great technologies that are now reducing our reliance on oil as a fuel source.

Matt appears to have not considered the impacts if he is wrong, and resources really are running out. If he is wrong, then humanity faces a catastrophe; if, on the other hand, the environmentalists are wrong and we reduce our consumption of resources, there appear to be no significant negative impacts on humanity, except perhaps for some mega-rich people whose wealth might not increase quite as quickly.

Investment in scientific research is always limited, and scientific discovery cannot be produced at will, so starting early on conservation, before we are certain there is a problem, appears wise.

Steven Campbell, via email

Earth's resources: is Matt Ridley being overly optimistic?

A REAL EYE-OPENER

Kev Lochun's article on the Voyager missions (September, p39) is excellent, but what I found almost heart-stoppingly beautiful are the late Carl Sagan's words to that picture of a "pale blue dot". I really think you should consider offering page 41 as a mounted print. It should also be on every politician's office wall…

Alan Moore, via email

SCRUBBING UP

I read with interest the 'Q&A' reply concerning hand-washing temperature (September, p85). It should be pointed out that the Rutgers University study referred to only used a small number of volunteers (21, apparently) and one type of bacteria.

The World Health Organization does not recommend any specific temperature for hand-washing, but I remember from school chemistry lessons – about 100 years ago! – that a chemical reaction's speed doubles for every 10°C. So would that not suggest that the efficiency of soap increases with a warmer water?

We are constantly reminded of the importance of good hand-washing for healthcare, and doing so in cold water just isn't comfortable. I wouldn't want anyone to be put off washing their hands!

G Sansom, North Wales

BBC FOCUS

EDITORIAL
Editor Daniel Bennett
Production editor Alice Lipscombe-Southwell
Commissioning editor Jason Goodyer
Online editor Alexander McNamara
Editorial assistant James Lloyd
Science consultant Robert Matthews
Contributing editors Emma Bayley, Russell Deeks

ART
Art editor Joe Eden
Designer Steve Boswell
Picture editor James Cutmore
Group art editor Susanne Frank

CONTRIBUTORS
Acute Graphics, Philip Ball, Robert Banino, Peter Bentley, Hayley Birch, Dan Bright, Verity Burns, Jamie Carter, JV Chamary, Charlotte Corney, Simon Crompton, Helen Czerski, Emma Davies, David Despau, Simon Falconer, Alex Franklin-Cheung, Maïté Franchi, Amy Godfrey, Alice Gregory, Alastair Gunn, Stephen Hall, Ryan Inzanu, Christian Jarrett, Matt Kimberley, Raja Lockey, Mark Lorch, Magic Torch, Lisa Moses, Helen Pilcher, Aarathi Prasad, Dean Purnell, Sara Rigby, Martin Sanders, Helen Scales, Kyle Smart, Rob Speed, Colin Stuart, Luis Villazon.

ADVERTISING & MARKETING
Group advertising manager Tom Drew
Advertising manager Neil Lloyd
Senior brand sales executive Jonathan Horwood
Brand sales executive Anastasia Jones
Senior classified executive Jenna-Vie Harvey
Newstrade manager Rob Brock
Subscriptions director Jacky Perales-Morris
Direct marketing manager Kellie Lane
Head of apps and digital edition marketing Mark Summerton

INSERTS
Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION
Director of licensing and syndication Tim Hudson
International partners manager Anna Brown

PRODUCTION
Production director Sarah Powell
Production coordinator Derrick Andrews
Ad services manager Paul Thornton
Ad coordinator Jade O'Halloran
Ad designer James Croft

PUBLISHING
Content director Dave Musgrove
Commercial director Jemima Dixon
Publishing director Andy Healy
Managing director Andy Marshall

BBC WORLDWIDE
President of UK and ANZ Marcus Arthur
Director of editorial governance Nicholas Brett
Director for consumer products and publishing Andrew Moultrie
Publishing director Chris Kerwin
Publisher magazines and NPD Mandy Thwaites
Publishing coordinator Eva Abramik
Contact UK.Publishing@bbc.com
www.bbcworldwide.com/uk--anz/ukpublishing.aspx

EDITORIAL COMPLAINTS
editorialcomplaints@immediate.co.uk

ANNUAL SUBSCRIPTION RATES (INC P&P):
UK/BFPO £63; Europe & Eire Airmail £66; Rest of World Airmail £70.

abc Audit Bureau of Circulations
58,368 (combined; Jan-Dec 2016)

IMMEDIATE MEDIA Co

BBC Focus Magazine is published by Immediate Media Company London Limited under licence from BBC Worldwide who help fund new BBC programmes.

PHOTO: ALAMY

Seeing is believing...

visionace®

with **vitamins A, B2** & **Zinc**
which help to maintain
normal vision

Visionace® is based on extensive research and has been expertly formulated with over 20 nutrients including Bilberry and Lutein, with specific nutrients to help support your vision.

ORIGINAL PLUS OMEGA-3 MAX

Britain's No.1 Vitamin Company*

*Nielsen GB ScanTrack Total Coverage Unit Sales 52 w/e 17 June 2017.

From Boots, Superdrug, Holland & Barrett, supermarkets, chemists, health stores
www.visionace.com

† A beneficial effect is obtained with a daily intake of 250mg of DHA.

45 YEARS VITABIOTICS Est. 1971

Made in Britain

VITABIOTICS
SCIENCE OF HEALTHY LIVING

2017-08-22 ADVISCONP E

PC Specialist recommends Windows Windows 10

15.6" COSMOS VI S

- 15.6" Matte Full HD IPS Screen
- Intel® Core™ i5-7300HQ
- 8GB Corsair 2133MHz
- 2GB GeForce GT 940MX
- 1TB SLIM SATA HDD (5,400)
- **Windows 10 Home**

This spec from **£729.99***

HYPERION ZEN

- AMD Ryzen 7 1700
- ASUS® CROSSHAIR VI HERO
- 16GB Corsair VENGEANCE 2133MHz
- 11GB GEFORCE GTX 1080 Ti
- 2TB WD BLACK
- **Windows 10 Home**

This spec from **£2,499.00***

APOLLO ZEN

- AMD Ryzen 5 1600X
- ASUS® PRIME B350-PLUS
- 16GB Corsair VENGEANCE 2133MHz
- 4GB AMD RADEON™ RX 570
- 250GB WD Blue™ SSD
- **Windows 10 Home**

This spec from **£949.00***

VANQUISH RX PRO II

- Intel® Core™ i5-7500
- ASUS® H110M-R
- 8GB Corsair VENGEANCE 2133MHz
- 8GB AMD RADEON™ RX 580
- 120GB KINGSTON UV400 SSD
- 1TB 3.5" SATA-III 6GB/s
- **Windows 10 Home**

This spec from **£889.99***

ENIGMA GT IV

- Intel® Core™ i3-7300
- ASUS® H110M-R
- 8GB Corsair VENGEANCE 2133MHz
- Integrated Graphics (HD)
- 1TB 3.5" SATA-III 6GB/s
- **Windows 10 Home**

This spec from **£489.99***

APOLLO K VR

- Intel® Core™i7-7700k
- ASUS® ROG STRIX Z270E GAMING - Wi-Fi
- 16GB Corsair VENGEANCE 2133MHz
- 8GB GEFORCE GTX 1080
- 250GB Samsung 850 EVO
- **Windows 10 Home**

COMPUTER SHOPPER RECOMMENDED

This spec from **£1,579.00***

0333 011 7000

/PCSPECIALIST @PCSPECIALIST

* Prices are including VAT and are correct at the time of printing, but subject to change.

pcspecialist

CUSTOM GAMING DESKTOPS & LAPTOPS

WWW.PCSPECIALIST.CO.UK

GET A FURTHER £15 OFF WITH THIS EXCLUSIVE VOUCHER CODE:

BBF57

ORDER ONLINE NOW AT WWW.PCSPECIALIST.CO.UK

HOW TO BEAT THE BURNOUT

Hectic lives don't have to go hand-in-hand with feeling drained. Read on to find out how the latest research will eliminate tiredness for good. Plus, turn to p42 for tips on banishing fatigue

WORDS: SIMON CROMPTON

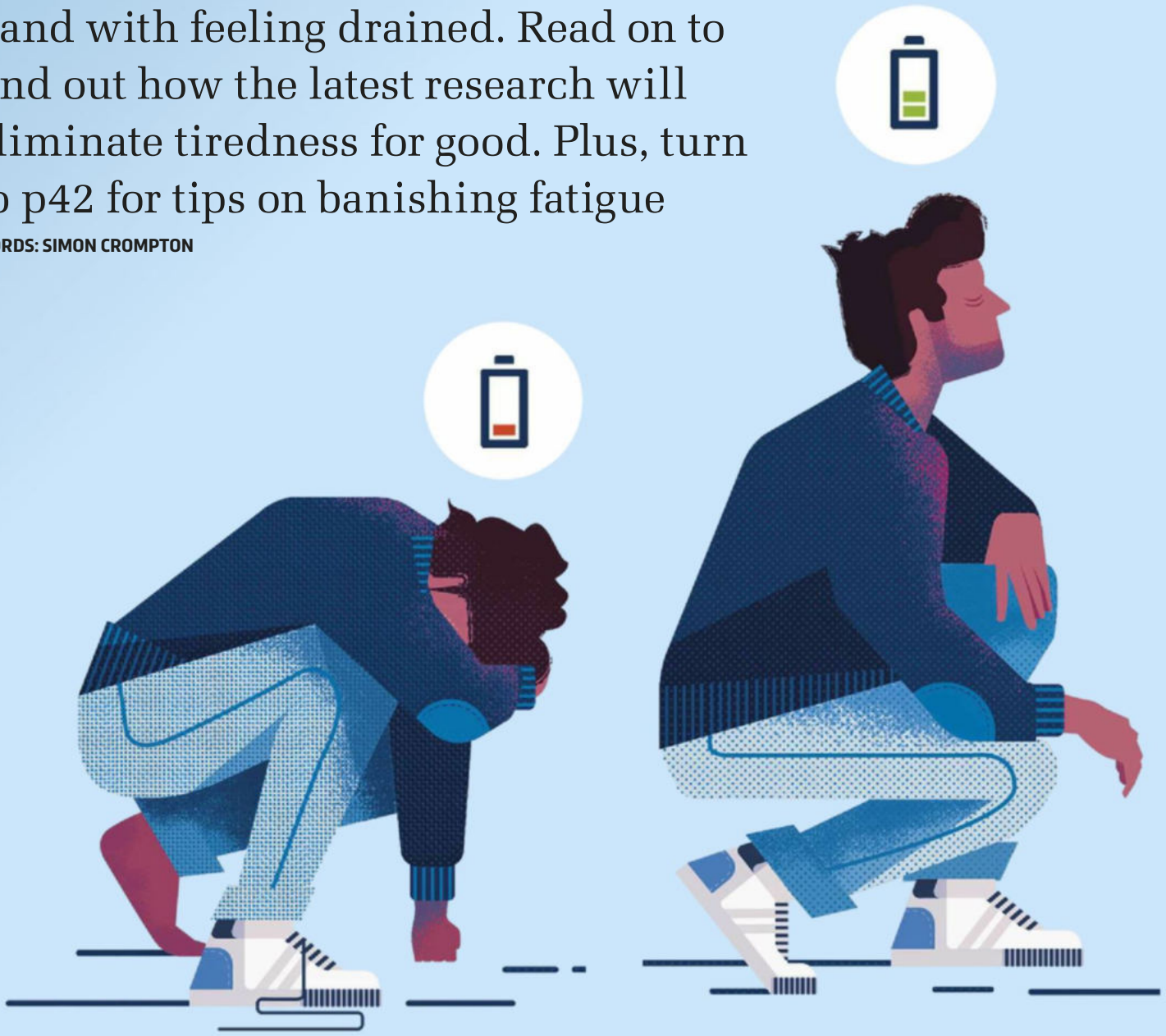


ILLUSTRATION: MAITÉ FRANCHI

Can you keep your eyes open long enough to read this feature? We won't be offended if you can't. The Royal College of Psychiatrists says that one in five of us feels unusually tired at any one time, and one in ten feels permanently fatigued. Tiredness and fatigue are behind 20 per cent of UK doctor consultations, according to a recent survey of GPs. No wonder doctors are regularly jotting down a handy new acronym – TATT (Tired All The Time) – in patient notes. Or that UK sales of energy drinks shot up by 155 per cent between 2006 and 2014. We are, it seems, an exhausted nation.

Tiredness is no joke. Sleep deprivation brings a heavy mental and physical toll. Around 20 per cent of accidents on major roads are sleep-related, according to the Department of Transport. Plus, people who are sleep-deprived lose the ability to be positive-minded, which researchers from the University of Pennsylvania say is likely to increase the likelihood of depression. There's also evidence that sleep deprivation increases the risk of obesity, heart disease, diabetes and stroke.

ven if you're getting enough sleep, feeling constantly fatigued can be bad for you. Research from the University of Alabama has found that working hard while fatigued increases blood pressure. This is because tired people increase their effort to make up for their diminished capability when they want to accomplish a task.

For those with conditions such as chronic fatigue syndrome (CFS/M) and cancer, it severely restricts quality of life. For millions of others, unexplained tiredness regularly rumbles in the background. Is there something wrong with us? Are we the victims of hectic 24-hour lifestyles? Why are we tired all the time?

Until now, little has been known about the biological processes that result in what we call tiredness or fatigue. Only in recent decades, with growing concern about the prevalence of conditions such as CFS/M , has research ●

"Some of us may simply have been born with a physical and psychological susceptibility to tiredness"

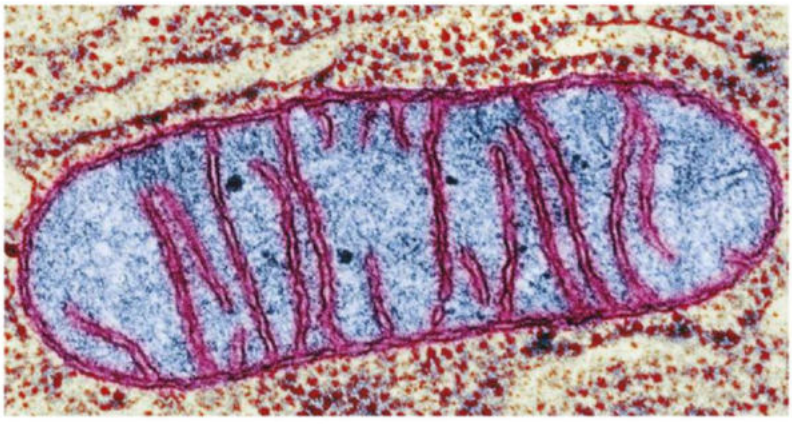
money been invested into the causes of long-term fatigue. And it is becoming clear that, although there is a wide spectrum of tiredness types, they are all linked and their causes interact.

Prof Julia Newton, director of the Newcastle Centre for Fatigue Research at Newcastle University, explains the causes of tiredness via a classic bell-shaped curve graph. "At the thin end of the curve, there are people who just need to get some sleep and get their lifestyle in order. At the other thin end of the curve there are clearly people who have diagnosed or undiagnosed illness that is causing fatigue. And then, there's everything else in the wide middle part of curve."

The wide middle is the complex bit, covering tiredness caused by combinations of many environmental, lifestyle and health factors. And recent research is beginning to reveal how genetics, cell function, inflammation and the brain's response to light may all have an underlying role in this tiredness 'mainstream'.

TIRED BODIES

At a cellular level, scientists are increasingly looking at the role of mitochondria – the power packs in every human cell – in determining how tired we feel. Mitochondria are miniature organs (organelles) that convert oxygen, sugar, fats and protein into a form of chemical energy, called ATP, which the body uses to fuel the brain and muscles.



BELOW: **A mitochondrion, a cell's 'power pack', has a highly folded inner membrane that's packed with substances involved in the creation of ATP, which the body uses for energy**

Diseases affecting the mitochondria cause fatigue, so recent reviews of research suggest that fatigue is closely associated with mitochondria not working properly because the body is not producing particular enzymes, for example.

Studies into CFS/ME by American fatigue expert Dr Robert Naviaux have shown that the condition is characterised by changes in mitochondria function. Naviaux believes that these changes may be triggered by stressors such as infection, or physical and psychological trauma.

Naviaux cites new literature indicating that stress can prompt metabolic changes which make organisms go into hibernation-like states such as torpor, diapause and aestivation. "Each of these is an energy conservation state that permits survival under conditions of environmental stress at the expense of a decrease in the ability to allocate energy for daily work or activity," he says. "Mitochondria are central control points for each of these processes."

This exploratory research about the metabolic origins of fatigue may link with other studies suggesting that sometimes tiredness has underlying but undiscovered physical origins. For example, recent studies have indicated that severe fatigue is associated with raised levels of leptin, a hormone produced in fat tissue which signals to the brain that the body has adequate energy stores. This raises the prospect that too much leptin – possibly from too much body fat – means we naturally feel less energetic: if we don't need food we don't need to go out and do something about it. This links with anecdotal evidence that intermittent fasting and reducing body fat can improve people's energy levels.

ARE YOU SLEEP-DEPRIVED OR FATIGUED?

Researchers use a simple sleep latency test to find out whether people who are constantly tired are sleep-deprived or fatigued for other reasons. If you lie down somewhere quiet during the day and fall asleep within a few minutes, then you are either lacking sleep or potentially suffering from a sleep disorder. If you don't drop off within 15 minutes, fatigue is the problem.

PHOTOS: GETTY X2

It also links with research indicating that people with CFS/M can have high levels of leptin and similar inflammation-producing substances called cytokines. Cytokines, which are also produced in fat, are released during immune responses. Studies have shown that low-grade inflammation robs mice of their energy to run on a wheel. This suggests that underlying tissue inflammation – whether it's in response to a virus, a long-term condition or a problem with cytokine regulation – can be enough to make us feel weary. Scientists in the Netherlands have now started a major new trial to find out whether anakinra, an anti-inflammatory drug that blocks a particular cytokine, brings an improvement in people with CFS/M .

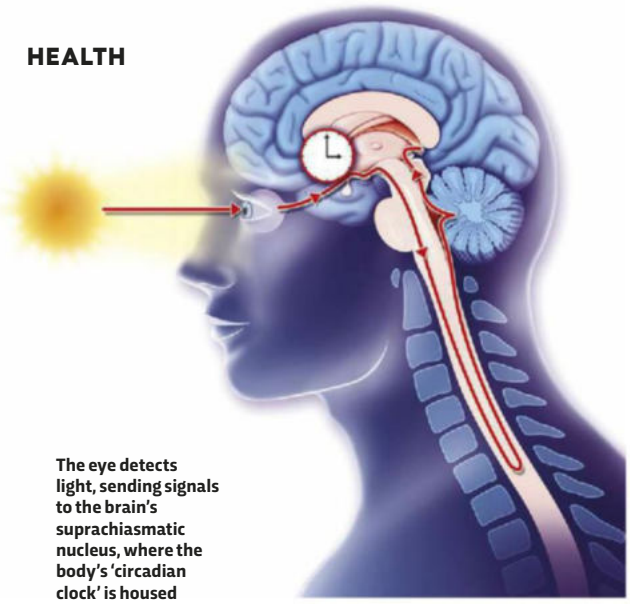
Newton is clear that these related underlying physical vulnerabilities may be a factor in everyone's continuing tiredness – not just those with a diagnosed condition. "The day-to-day fatigue that GPs see definitely relates to chronic illness. The two aren't separate," she says.

NATURALLY SLEEPY

There's new research to suggest some of us may simply have been born with a physical and psychological susceptibility to tiredness. Researchers from the University of dinburgh analysed the genetic make-up of 111,749 people who indicated they felt tired in the two weeks before samples were collected for the UK Biobank. They found a genetic link between those who reported tiredness and those prone to diabetes, schizophrenia, high cholesterol or obesity. "This raises the possibility of a genetic link between tiredness and vulnerability to physiological stress," said the team, led by Prof Ian Deary. However, the researchers also said that the majority of people's differences in self-reported tiredness can be put down to environmental causes rather than genetic factors. So how we live our lives, and what happens to us, is of first importance.

And the significance of our relationship to daylight is becoming increasingly clear. For decades, we've been told that keeping regular habits and sleeping hours is important. Now, research has confirmed the importance of a part of the brain called the suprachiasmatic nucleus (SCN), a group of cells in the hypothalamus that responds to light signals fed from the eye. When it's light, the SCN messages other parts of the brain to release hormones which make us feel alert, and when it's dark it signals for the release of hormones that make us feel sleepy, like melatonin.

If our habits are regular, our brain adjusts to release hormones at the right time. If they're not, we end up in constant conflict with our natural circadian rhythm. The blue imitation daylight emitted from computer screens and smartphones



The eye detects light, sending signals to the brain's suprachiasmatic nucleus, where the body's 'circadian clock' is housed

can confuse our SCN further, especially if we're using our screens at night. Our brain is tricked into thinking it's day when it's not, and we end up feeling awake when we should be sleepy, so we don't get such a good night's rest.

There's increasing public and scientific interest in using what are known as 'chronobiotic agents' to adjust the body clock to counter sleep problems, tiredness and mood disorders. Studies investigating whether taking melatonin tablets reduces fatigue have been mixed, and doctors warn against overuse of the supplement. But some new types of antidepressants, such agomelatine, work by

NEVER BE TIRED AGAIN

THE SEVEN CAUSES OF FATIGUE AND HOW YOU CAN BEAT THEM

SOCIAL JETLAG

Many of us like to treat ourselves to a weekend lie-in after getting up early for work all through the week. But going to sleep and waking up at different times can disrupt your circadian rhythms – the brain's natural timing of sleep and wakefulness hormone release. This 'social jetlag' is associated with sleepiness, feelings of fatigue, bad mood and health problems.

A recent study from the Sleep and Health Research Program at the University of Arizona suggests that each hour of weekday to weekend lag brings an 11 per cent increase in the likelihood of heart disease.

Tip: Avoid weekend lie-ins and late nights, and keep to the same sleep-wake pattern whether you're a night owl or a morning lark. Using an app or a tracker to chart your sleep patterns can help.

LACK OF EXERCISE

Although excessive exercise can cause short-term fatigue, long-term tiredness is associated with too little activity. A University of Georgia review of research found 90 per cent of studies agree that people who regularly exercise report less fatigue than groups who don't. Exercise increases levels of energy-promoting and mood-enhancing neurotransmitters such as dopamine, norepinephrine and serotonin. It also resets the SCN, the part of the brain that regulates sleep and wakefulness hormones. And exercise reduces fat stores, which seem to be associated with long-term fatigue.

Tip: Try and find forms of exercise that fit in with your lifestyle and what you enjoy, rather than automatically investing in a gym membership. This way, you'll probably be more inclined to stick to it.

CABIN FEVER

Light, fresh air and stimulation are all important for brain health and SCN functioning, so being cooped up indoors all the time can worsen mood and lower energy levels. We're particularly prone to this during the winter, when days are dark, we're stuck indoors, and short-term cabin fever can eventually become seasonal affective disorder (SAD). SAD, characterised by depression and feelings of tiredness, is believed to be caused by lack of sunlight, which disrupts the brain's production of mood and sleep-regulating brain chemicals such as melatonin and serotonin.

Tip: Try and pop outdoors every couple of hours, even if it's just for a few minutes. It will clear your brain and may help with lethargy and fatigue. Go outside during your lunch break, rather then spending it at your desk.

PHOTOS: SCIENCE PHOTO LIBRARY, GETTY X7

regulating circadian rhythms and there's evidence they improve daytime functioning and reduce fatigue.

Some of us are tired for the simplest of reasons, yet unaware of it, says Newton. She sees hundreds of patients in her fatigue clinic in Newcastle, and for many the cause is almost too obvious for them to see. "It's amazing how many people don't associate their daytime fatigue with poor night-time sleep," she says. "Sometimes it's simply a matter of getting enough sleep. People tend to just carry on doing what they've always done and don't rest properly.

"People are amazed when I ask them to do an activity diary, and then I ask: 'Well, when actually do you rest?' And they say: 'I'm resting here, when I'm on Facebook'. And I have to tell them, sorry, but that's not resting.

"We're in a society on a treadmill. We're all push, push, push. And sometimes that just isn't sustainable, physically and mentally."

Simon Crompton is a freelance writer and editor who specialises in science, health and social issues. He tweets from @Simoncrompton2

DIET

Being overweight can cause tiredness because your body is having to work harder to perform everyday activities. It also increases your risk of a condition called obstructive sleep apnoea – where the tissues in the throat collapse during sleep, causing airway blockage. This leads to constant sleep interruption and daytime tiredness.

What you eat is also important. Low levels of iron and B vitamins can cause tiredness. And having a diet high in fast-burning sugary carbohydrates, like cakes and biscuits, can leave you feeling tired when the energy rush quickly wears off.

Tip: Dietitians recommend a balanced diet, including complex carbohydrates such as wholemeal bread, brown rice, beans, oats and pulses which are slowly metabolised by the body and lead to less of an energy dip.

CAFFEINE AND ALCOHOL

The trouble with drinking coffee is that you need to keep drinking it: one of the commonest symptoms of caffeine withdrawal is fatigue. Research from the Johns Hopkins Medical School found that although caffeine drinkers think their drink of choice improves their performance and mood, in fact it just counteracts the adverse effects of caffeine withdrawal by bringing them back to normal levels of functioning.

Alcohol causes tiredness too. Short-term, it can result in restless sleep and dehydration. Long-term, it can lead to anxiety and depression, which are linked to lethargy and sleeplessness.

Tip: Test whether caffeine or alcohol are the culprits for making you tired. Don't drink them for at least a week, so you get over any withdrawal symptoms, and see whether you start feeling better.

DRUGS

Fatigue can be caused be prescribed and recreational drugs. It has been reported as a side effect of statins, allergy medications, hormone therapy and many cancer treatments. According to Frank, the drug information organisation, the high experienced with drugs such as cocaine, speed and ecstasy is often followed by a comedown of tiredness and depression. Scientists at Imperial College London demonstrated that smoking marijuana long-term lowers levels of brain dopamine – a chemical that plays a key role in how we experience motivation, pleasure and reward. This can result in a lack of energy and motivation.

Tip: If you're on prescription medications, look up possible side effects on the leaflet that comes in the box. Visit your doctor or pharmacist to discuss any concerns. For info about drugs, visit **talktofrank.com**

WORRY AND DEPRESSION

Lack of sleep and fatigue are strongly linked with depression and anxiety. Some researchers believe that widespread depression could be the reason why so many of us feel constantly tired. Studies carried out by the Texas A&M Institute for Neuroscience back up this link. Researchers measured brain oxygen levels when people undertook various physical and mental tasks, and found that they fatigued more quickly when completing complex mental activities. The brain's resources were being divided. So stress and mental frustration are likely to make us tire more easily, the researchers say.

Tip: Try an NHS quiz at **bit.ly/mood_quiz** to help establish whether your state of mind is behind your tiredness. If you're concerned that you or a loved one is suffering from depression, visit your doctor.

BBC FOCUS

FOP312

SUBSCRIPTION ORDER FORM

Please complete the order form and send to:
FREEPOST IMMEDIATE MEDIA *(please write in capitals)*

UK DIRECT DEBIT

☐ Yes, I would like to subscribe to/renew *BBC Focus* and pay £17.95 every six issues – saving 40% **(please complete form below)***

YOUR DETAILS (ESSENTIAL)**

Title _____ Forename _____

Surname _____

Address _____

_____

_____ Postcode _____

Home phone no _____

Mobile phone no _____

Email _____

☐ **I wish to purchase a gift subscription**
(please supply gift recipient's name and address on a separate sheet)

Instructions to your bank or building society to pay by Direct Debit

DIRECT Debit

To: the Manager (bank/building society)

Address

Postcode

Name(s) of account holder(s)

Bank/building society account number | **Branch sort code**

Reference number (internal use only)

Originator's identification number

7 1 0 6 4 4

Please pay Immediate Media Co Bristol Ltd debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Immediate Media Co Bristol Ltd and, if so, details will be passed electronically to my bank/building society.

Signature | Date / /

Banks and building societies may not accept Direct Debit mandates from some types of account

Your personal information will be used as set out in our privacy policy, which can be viewed online at **immediate.co.uk/privacy-policy. Immediate Media Company Limited would love to send you newsletters, together with special offers, and other promotions. Please tick here if you'd prefer not to receive these by email ☐ text message ☐ regular post ☐ telephone ☐

Branded BBC titles are licensed from or published jointly with BBC Worldwide (the commercial arm of the BBC). Please tick here ☐ if you'd like to receive regular newsletters, special offers and promotions from BBC Worldwide by email. Your information will be handled in accordance with the BBC Worldwide privacy policy which can be viewed online at **bbcworldwide.com/privacy.aspx**

OTHER PAYMENT METHODS

☐ **UK cheque/credit/debit card** – £52.40 for 14 issues, **saving 25%**

☐ **Europe** inc Eire – £73.35 for 14 issues

☐ **Rest of world** – £74.75 for 14 issues

☐ I enclose a cheque made payable to Immediate Media Co Ltd for £ _____

Visa ☐ Mastercard ☐ Maestro ☐

☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐ ☐☐☐☐

Issue no ☐☐ Valid from ☐☐☐☐ Expiry date ☐☐☐☐

Signature _____ Date _____

If credit card address is different, please use the order hotline 03330 162 113

OVERSEAS Please complete the order form and send to:
BBC Focus Magazine, PO Box 3320, 3 Queensbridge, Northampton, NN4 7BF

***Offer ends 13 October 2017.** 40% saving is only available to UK residents paying by Direct Debit. Your subscription will start with the next available issue.

You may photocopy this form

SPECIAL SUBSCRIPTION OFFER

SAVE 40% ON THE SHOP PRICE!

SPREAD THE COST AND PAY JUST
£17.95 EVERY 6 ISSUES
BY DIRECT DEBIT!*

RECEIVE EVERY ISSUE DELIVERED DIRECT TO YOUR DOOR WITH **FREE UK DELIVERY**

HURRY! OFFER ENDS
13 OCTOBER 2017

NORMALLY ~~£4.99~~
YOU PAY
£2.99

SPACE TOURISM GETS REAL

Elon Musk has pencilled in a date in 2018 to send two tourists around the Moon and back on SpaceX's Falcon 9 rocket. Here are 10 things you need to know before you buy yourself a ticket...

Words: **Colin Stuart**

PayPal founder and Tesla boss Elon Musk isn't a man who thinks small – nor is he short of a few million dollars to chuck at any obstruction in his path. Which is why SpaceX – the company he founded in 2002 with a view to developing cheaper, faster, longer-distance space travel, and ultimately colonising Mars – has become the world's leading private spaceflight provider.

The list of spaceflight 'firsts' that SpaceX has racked up over the course of the past 15 years is a long one. Among other achievements, it was the first private company to put a liquid-fuelled rocket into Earth orbit (Falcon 1, 2008); the first to send a spacecraft to the ISS (Falcon 9, 2012); the first to put a satellite into geosynchronous orbit (Falcon 9, 2013), and the first to relaunch and land a 'used' orbital rocket (Falcon 9, 2017).

As you can see, the reusable Falcon 9 rocket has been the key to many of SpaceX's successes. Long term, Musk's eyes remain firmly fixed on the Red Planet, but in the meantime, let's take a closer look at this 69.9m-tall behemoth, which has now racked up 38 successful flights and is fast becoming the go-to option for getting payloads and people into space…

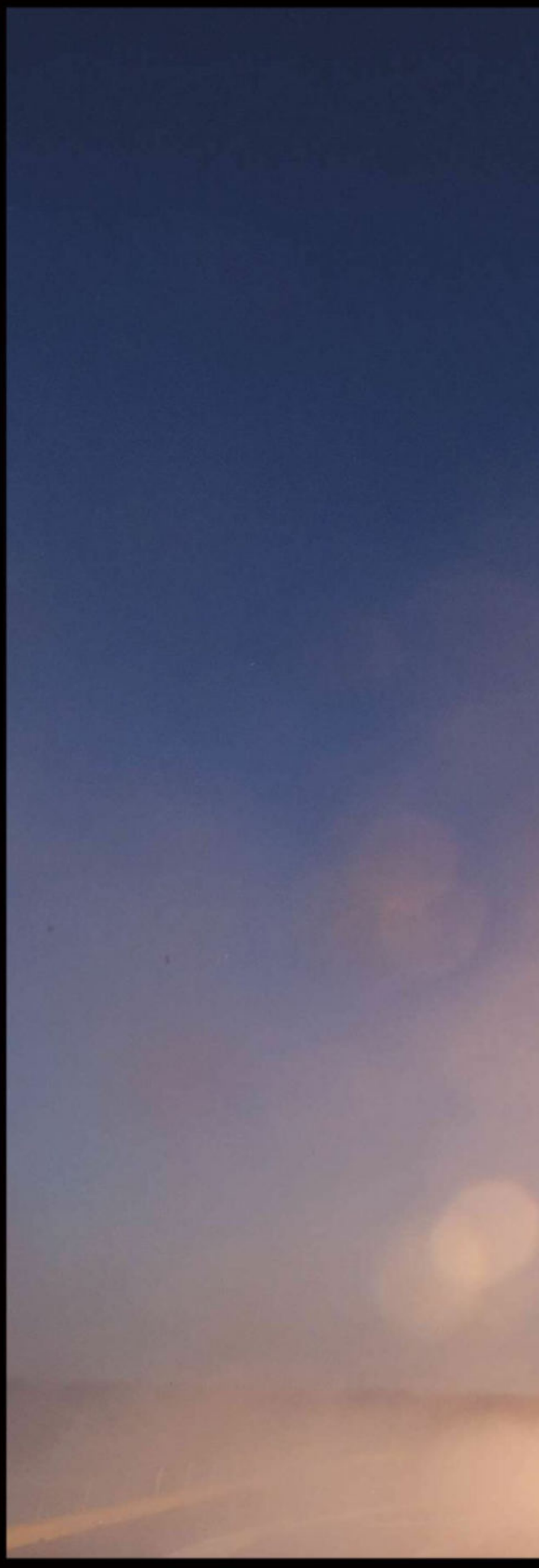


PHOTO: SPACEX

1

IT'S REUSABLE

When SpaceX launched a communications satellite into orbit in March 2017 they made a little piece of space history. It was the first time an orbital rocket had be reused – it had already been to space and back in April 2016.

The Falcon 9's first stage – the bit with most of the fuel and the main engines – is brought back to the ground and collected to fly again. This could be a game-changer for space exploration because that's the most expensive part of the rocket. Previously, each time you wanted to go to space you had to fork out hundreds of millions of dollars for a brand new rocket. Now the same one can be used multiple times.

SpaceX is offering its customers a discount of up to 30 per cent if they opt to fly their payload on a reused Falcon 9, cutting the cost of getting to space even further.

2

IT'S RELIABLE

The Falcon 9 rocket boasts a 95 per cent success rate. There have been 41 launches since the first in 2010, and all but two achieved their stated goals. One failed to reach orbit, the other exploded on the launchpad during a pre-flight test.

This compares well to the rest of the rocket industry, where the average failure rate is also 5 per cent. NASA's Space Shuttle, which ferried astronauts to and from orbit, had a success rate of 98.5 per cent, with the famous Challenger and Columbia disasters notable black marks. The Russian Soyuz rocket, which is currently the only way to get people to the International Space Station, has seen over 1,700 launches and has a 97 per cent success rate.

If SpaceX wants to start using its technology to send people to space, then perhaps it will have to boost its success rate a little to bring it in line with these other benchmarks.

3

IT COULD INSPIRE A GENERATION

NASA's Apollo missions did a lot more than just land 12 astronauts on the Moon. A whole generation watched on as human beings ventured out onto a new world for the very first time. Those unprecedented steps fired up the imaginations of countless young people worldwide, many of them turning to careers in science, maths and engineering as a result.

But humans have languished in low Earth orbit ever since Apollo 17 departed from the lunar surface in 1972. Yes, we have the International Space Station, but don't underestimate the power of seeing humans push new boundaries. If private space companies can return people to the Moon, or even send them to Mars, their exploits will be beamed around the world in an era now equipped with HD cameras, social media and 24/7 news channels. The inspirational effect of those missions would be unrivalled. Who knows what this generation might be inspired to do next?

SpaceX engineers inspect one of the Falcon 9's interstage sections prior to assembly

4

IT'LL KICK-START NEW INDUSTRIES

In the past, the huge costs of space launches meant only those with the broadest shoulders could afford the astronomical sums involved. That used to mean governments. But governments are funded by taxpayers, many of whom are sceptical about the merits of space exploration when they see more pressing concerns closer to home.

SpaceX is blazing a trail for the true commercialisation of space by proving that it can be done well for less. Now other companies are also springing up, looking for a slice of action. Billionaires Jeff Bezos and Richard Branson are already putting their money on the line. The global space industry is growing rapidly, consistently outpacing even the Chinese economy. As a result, companies that were priced out of space before are beginning to think that it might be affordable after all. The fleets of satellites that these companies inexpensively put into orbit will help run innovative new technologies including autonomous vehicles and super-fast internet connections.

5

IT'S POWERFUL

The power behind the Falcon 9 is the Merlin engine, which is built in-house by SpaceX. Nine of these engines are clustered together in the first stage, while the second contains a single Merlin that's modified to fire in the vacuum of space. The engines burn a mixture of rocket-grade kerosene and liquid oxygen. On a typical launch, the first stage engines burn for 162 secs, and the second stage engine burns for 397 secs.

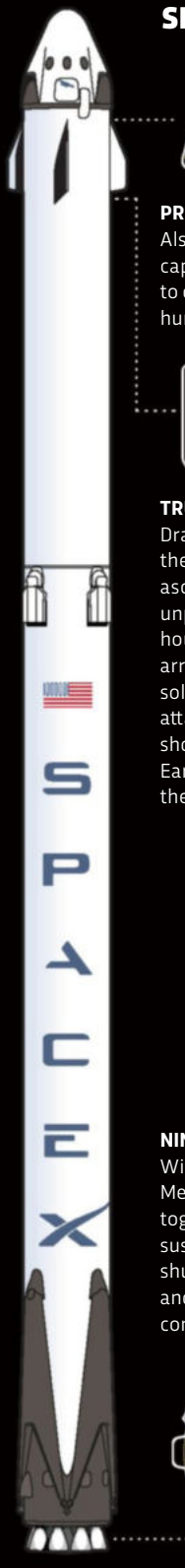
The powerful Merlin is one of the most efficient engines ever built. Having nine of them in the first stage also offers some built-in safety. On other rockets, if an engine fails during launch, the lost thrust can destroy the payload's chance of successfully reaching orbit. But the Falcon 9 is designed so that two of the nine Merlin engines in the first stage can fail and the launch won't be affected. The healthy engines can burn longer, picking up the slack to save the mission.

A Merlin engine being prepared for testing. The Falcon X carries 10 of these engines

PHOTO: SPACEX X2

FALCON 9 HOW IT WORKS

The Falcon craft have been a decade in the making. Here's what you need to know about the rocket and the capsule

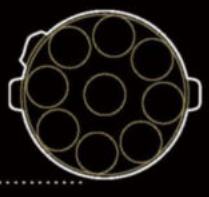


DRAGON SPACECRAFT

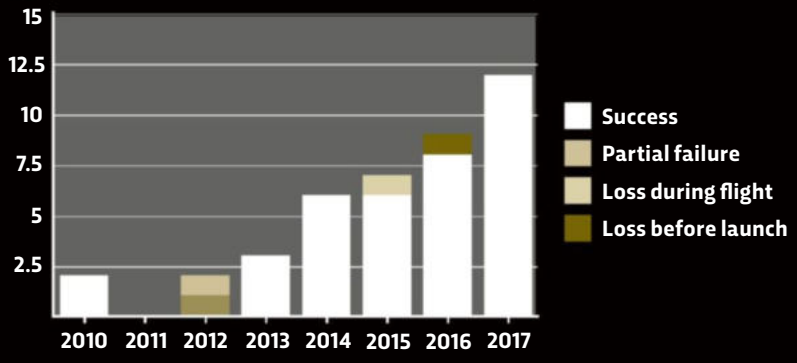
PRESSURISED SECTION
Also referred to as the capsule, this is designed to carry both cargo and humans into space

TRUNK
Dragon's trunk supports the spacecraft during ascent to space, carries unpressurised cargo and houses Dragon's solar arrays. The trunk and solar arrays remain attached to Dragon until shortly before re-entry to Earth's atmosphere, when they are jettisoned

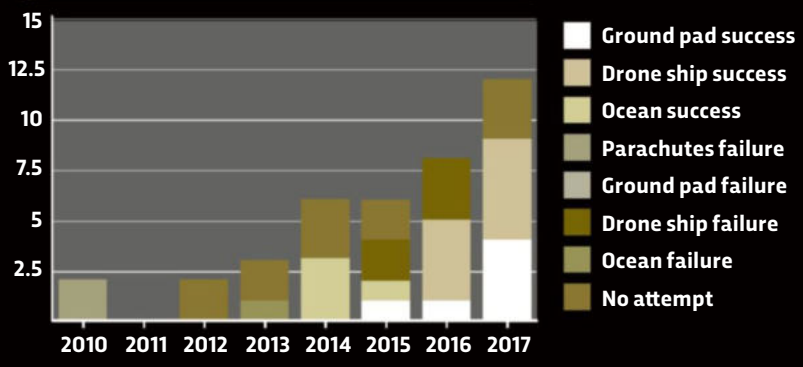
NINE MERLIN ENGINES
With its nine first-stage Merlin engines clustered together, Falcon 9 can sustain up to two engine shutdowns during flight and still successfully complete its mission



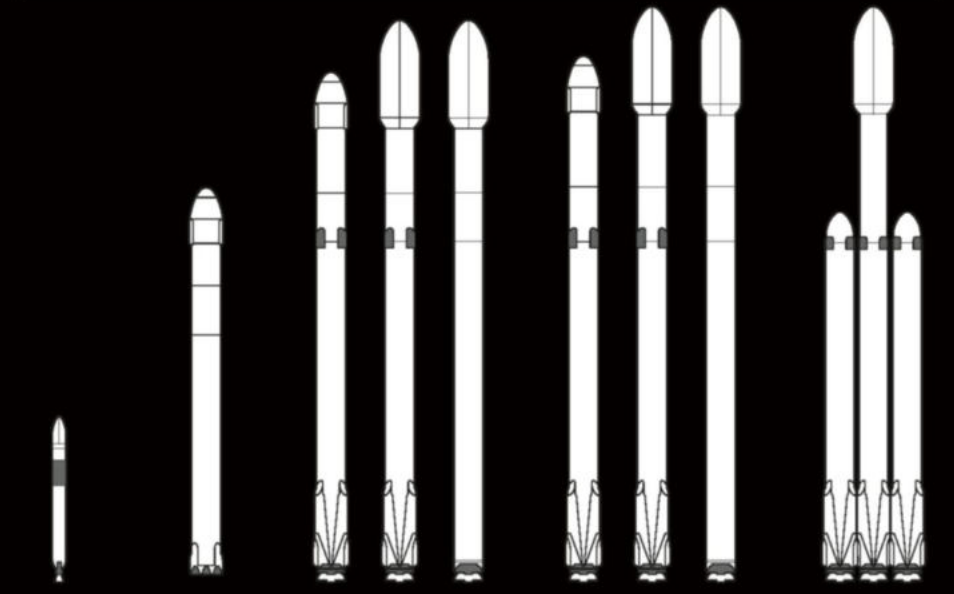
FLIGHTS BY MISSION OUTCOME



FLIGHTS BY LANDING OUTCOME



ROCKET EVOLUTION



FALCON 1
2006-2009

FALCON 9 V1.0
2010-2012

FALCON 9 V1.1
2013-2014

FALCON 9 V1.2 (FT)
2015-PRESENT

FALCON HEAVY
NOV 2017?

FALCON 9 LAUNCH TIMELINE

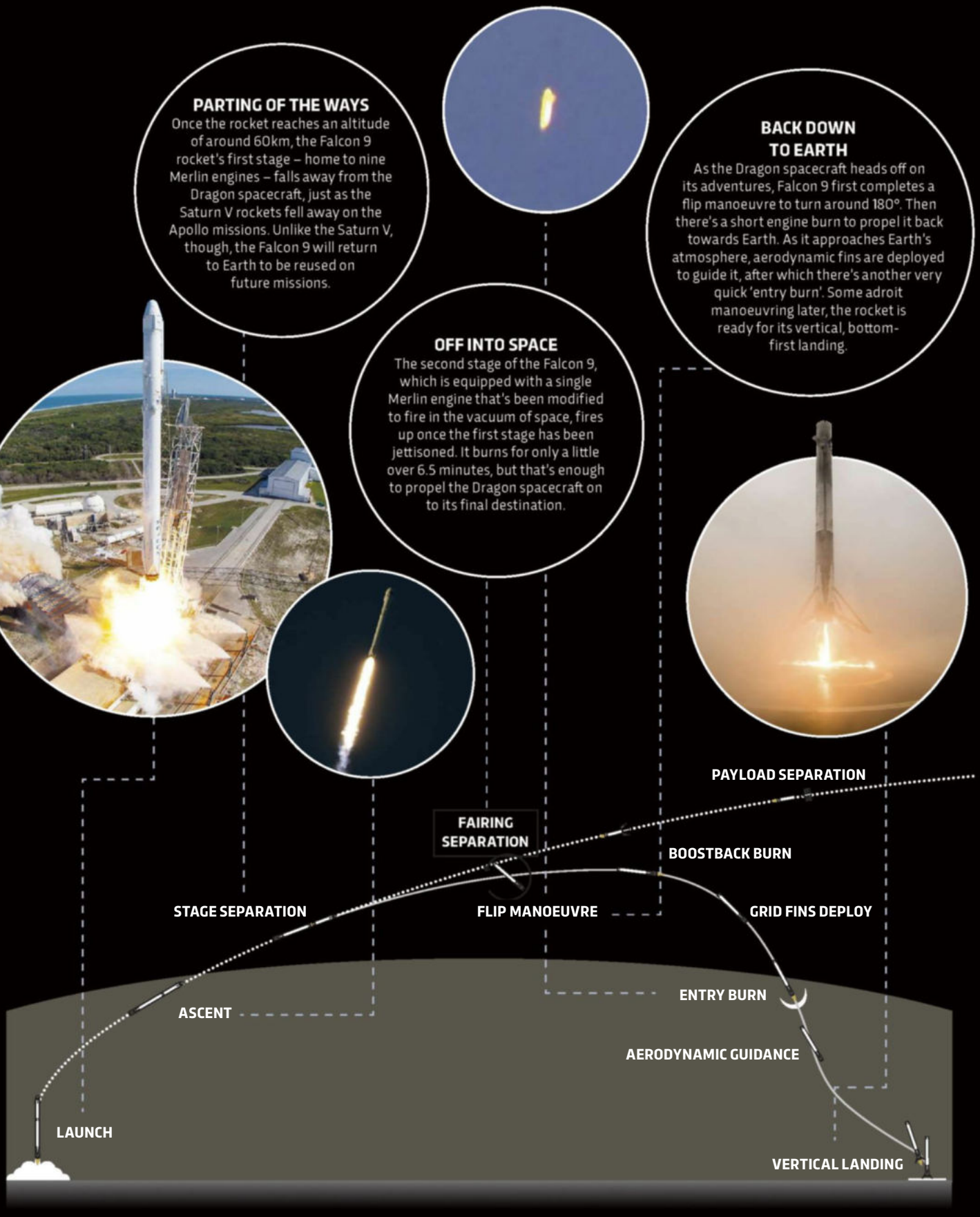


PHOTO: SPACEX X4 ILLUSTRATION: ACUTE GRAPHICS

6

IT CAN LAND AT SEA

So far, all launches have taken place from one of three land-based launch sites. However, some landings have taken place out at sea. After five unsuccessful attempts, the first flawless landing on a floating drone ship came in April 2016. This is key because landing at sea requires less fuel than returning to the launch site, and expending less energy in the landing means there's more energy available to reach a higher orbit. Touching down on water is also safer if anything goes wrong.

The two floating barges – *Of Course I Still Love You* and *Just Read The Instructions* – are named after spaceships in the Iain M Banks novel *The Player Of Games*. The former is stationed in the Atlantic Ocean to pick up rockets launched from Cape Canaveral, Florida, the latter in the Pacific to collect missions launched from Vandenberg Air Force Base, California.

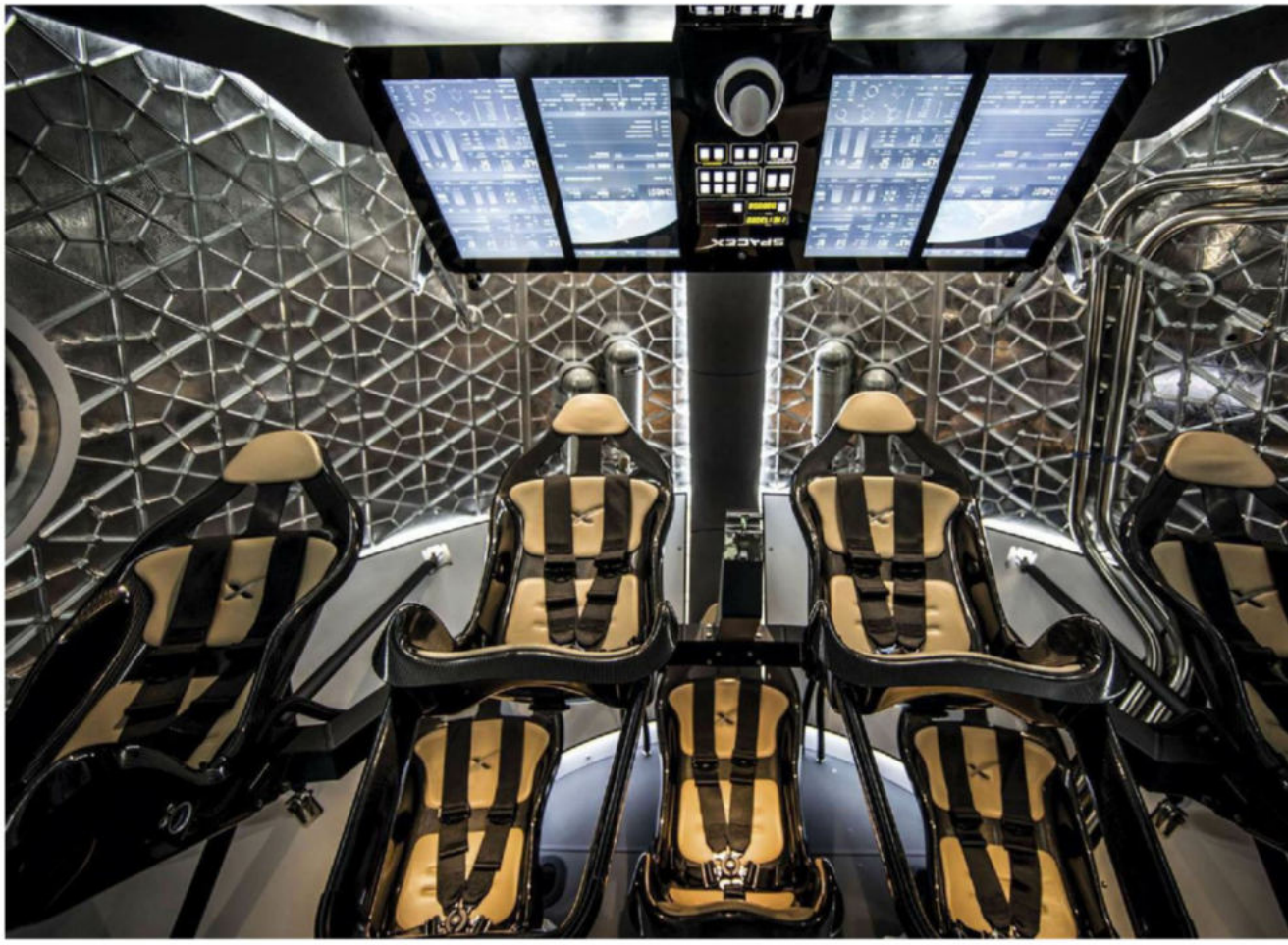
7

IT'LL LAUNCH PEOPLE ONE DAY

SpaceX has already successfully used its re-usable Dragon capsule to deliver cargo to the International Space Station – the first time that was done by a private company. Launched on top of the Falcon 9 rocket, its true purpose is to send people into space. Four windows will provide the lucky astronauts with a stunning view.

The next version of Dragon – Dragon 2 – will make its first delivery to the ISS in November this year. It'll be launched on the new Falcon Heavy rocket, which will also be making its maiden flight. Elon Musk has even announced his intention to send two paying customers around the Moon in a Dragon 2 capsule and return them to the Earth. Remarkably, he says this will happen at the back end of 2018. Given that only one government has ever achieved this feat before, it would be some statement of intent.

A Falcon 9 rocket touches down one of the two offshore landing platforms



PHOTOS: SPACEX X2, GETTY

8

◂ IT'LL BOOST SPACE TOURISM

Even if two paying punters don't end up getting sent around the Moon in a week-long mission next year, it's easier to see SpaceX launching tourists into Earth orbit.

In the decades to come, travelling into space will become as common as getting on a plane. The first trans-Atlantic flights cost thousands of dollars in today's money, but now the ocean can be crossed for a few hundred. Similarly, a successful launch of customers into orbit by a private company will generate even more competition and drive down the price for all of us.

Don't be surprised if the children at school now are holidaying in space for a few days later in their lives. For the price of a round-the-world cruise or a top of the range car, they could be looking down on the rest of us from orbit as they float in a Dragon capsule.

PHOTO: SPACEX

9

IT COULD TAKE US TO MARS ONE DAY

It's no secret that Elon Musk's ultimate goal is to get people to Mars. However, that feat is leagues ahead of escorting astronauts into Earth orbit.

Musk's vision involves SpaceX's Interplanetary Transport System (ITS). The aim is to eventually park up to 1,000 spaceships in Earth orbit, each with a crew of 100. They'll await the optimal window to head for Mars and depart *en masse*. This happens every 26 months when the gap between the planets is narrowest. Musk's publicly stated ambition is to get a million people to Mars within the next 50 to 100 years.

The Red Planet still presents significant hurdles, however. The radiation exposure on the six-month voyage would be unacceptably high, so the crew will need shielding. Slowing down sufficiently to land safely on Mars is a real challenge, too, as is keeping a crew supplied with enough food, water and energy for such a long journey.

10

THERE'S STILL A FEW KINKS TO IRON OUT

There's a reason why many commentators baulked when Elon Musk announced his vision of a Moonshot as early as next year. Space travel is still difficult, especially with heavy payloads beyond Earth orbit. NASA managed it in the 1960s and 70s, but only by throwing a huge amount of money at the problem. In the years running up to the first Moon landing, NASA's budget was over 4 per cent of US GDP – the largest economy in the world.

As a private company, SpaceX's books are secret, so we don't know how much money it's pumping into space exploration or how likely it is that its efforts will ever be profitable. If all goes to schedule then SpaceX should deliver astronauts to the International Space Station next year, and a lot will depend on how that goes. Glitches could put back any subsequent human flights significantly, but it wouldn't be the first time SpaceX has done something unprecedented.

Colin Stuart is a fellow of the Royal Astronomical Society. His books include *13 Journeys Through Space And Time*, *Why Space Matters To Me* and *Physics In 100 Numbers*.

CRAZY IN LOVE

How many sexes are there? Two, right? Not if you're a clam shrimp – then there are three, while other organisms have hundreds or even thousands of 'mating types'. Such weird mating strategies evolve by chance, but can result in better odds of finding a match. Here are some species that scientists have discovered that do things a little differently...

WORDS: **HAYLEY BENNETT**

YOUR PLACE OR SLIME?

Slime moulds are weird. Sometimes they're single cells. Sometimes they're clumped together as giant, oozing masses that act as one. *Physarum polycephalum*, a common slime mould that lives on decaying leaves, spends most of its time clumped together. It's basically a slimy, yellow bag, full of thousands of DNA-containing nuclei, that can crawl across a surface. And its mating habits certainly don't make it any less weird. The slime mould releases spores that become sex cells. In order to mate, two spores must meet and merge sex cells, which have different sexes or 'mating types' depending on which variants of certain genes they carry. Estimates of its number of mating types range from 13 to over 500.

THREE IS THE MAGIC NUMBER

Unlike in humans, where – other than in rare cases – the sex chromosomes X and Y can only pair as XX (female) or XY (male), these fingernail-sized freshwater crustaceans have an equivalent of YY. The sex chromosomes of the Texas clam shrimp (*Eulimnadia texana*) are called W and Z, and can pair as WW, ZW or ZZ, giving them a third sex. WW and ZW are hermaphrodites, and the ZZs are males. Hermaphrodites can't mate with other hermaphrodites because they don't have the male 'claspers' needed to get a good grip on their mates, but as well as pairing with males, they can self-fertilise their own eggs. As a sort of backup plan, they continue to do this even when pairing.

JUST THE 28,000 OF US

The split gill fungus (*Schizophyllum commune*), which grows on rotting wood, has at least 28,000 different mating types. But what is a mating type? Some experts think there can only truly be sexes if there are ways to tell them apart physically. If there are only genetic differences, then they are referred to as 'mating types'.

Sex in this species of fungus is determined by two genes, on two different chromosomes, with hundreds of possible gene variants. Mating occurs between airborne spores. If any of the gene variants in the partnering spores match, no offspring are produced, ensuring that a parent mushroom can't breed with most of its offspring. Outside its immediate family, the parent can mate with almost anyone – about 99.98 per cent of the population, in fact.

OPPOSITES ATTRACT

Birds are usually male (ZZ) or female (ZW), but the white-throated sparrow (*Zonotrichia albicollis*) behaves as though it has four sexes. Scientists believe that this is because it is in the process of evolving a second set of sex chromosomes. Both males and females can have white or tan stripes on their heads, and will only mate with the opposite sex and opposite stripe colour. In breeding terms, this works out as a disadvantage because it means each bird only has one-quarter of the population to choose from. Some scientists think that the strategy is unsustainable, and one of the colour types will eventually disappear.

EN GARDE!

Some species aren't very good at spotting or chasing after potential mates. So making every member of the population a potential mate is the best strategy. For many flatworms this means a hermaphroditic lifestyle where everyone you meet has testes as well as ovaries – the sex organs for both males and females. Some marine flatworms like the tiger flatworm (*Maritigrella crozierae*) have organs called stylets that they use as swords to stab each other in order to transfer sperm. This bizarre spectacle, known as 'penis-fencing', can sometimes inseminate both partners during a single match.

THE MAGNIFICENT SEVEN

As long as no one is overly choosy, adding a few more sexes to the standard two can really boost the odds of meeting a mate. This is how it works for *Tetrahymena thermophila*, a freshwater, single-celled organism with seven sexes. Any member of one of the seven sexes can breed with any member of the other six sexes. It's like being able to make babies with 86 per cent of the population instead of a mere 50 per cent as with our two-sex strategy. This organism carries the DNA for all seven sexes, deleting the unnecessary fragments of DNA only when it comes to reproducing.

PHOTOS: ALAMY, HUGH LANSDOWN/FLPA, SCIENCE PHOTO LIBRARY, BBMEXPLORER.COM, GETTY, JEAN-FRANCOIS CART/FLPA

Special offer for FOCUS readers

ISSUES FOR JUST £10*

Celebrate our 10th birthday with a subscription to *BBC Countryfile Magazine!*

Subscribe online **www.buysubscriptions.com/CF10BFH**

Or call on **03330 162 112†**

please quote **CF10BFH** offer ends 16 October 2017

†Calls from landlines will cost up to 9p per minute. Call charges from mobile phones will cost between 3p and 55p per minute but are included in free call packages. Lines are open 8.00am - 8.00pm weekdays and 9.00am - 1pm Saturdays. *10 issues for £10 offer is only available to UK residents paying by Direct Debit. After your first 10 issues your subscription will continue at £18.95 every 6 issues. If you cancel within 2 weeks of receiving your 9th issue you will pay no more than £10. BBC Countryfile Magazine is published 13 times a year. Your subscription will start with the next available issue. Offer ends **16 October 2017**

HELEN CZERSKI ON... STATIC ELECTRICITY

"AN UNLUCKY SCRAP OF SILK WAS ABOUT TO BECOME A SCIENCE EXPERIMENT, RATHER THAN A DRESS"

Surrounded by lovingly coordinated racks of beautiful fabrics, and hushed discussions about bias cuts and fancy stitching, I felt as though I was about to commit the ultimate fabric shop sin. It wasn't asking for pure silk that was the problem. It was admitting that some unlucky scrap of fabric was about to be denied the glory of becoming an evening dress, and would instead find a home in a science experiment. This is because I had read that silk is the perfect material with which to charge a plastic comb with static electricity. The assistant raised his eyebrow and left me to it.

The next day we did the demo and the silk had its moment of glory. Except that it didn't. When rubbed along the comb, my cotton T-shirt did just as well or just as badly, depending on how you look at it. Neither one charged the comb reliably. And so I did some digging to find out why.

At the heart of all these static electricity demos is a simple principle: when two materials are rubbed together, some electric charges hop from one to the other, giving each object a residual electric charge (which we call static electricity). This is the triboelectric effect. It's most obvious for electrical insulators in dry air, because the charge that is generated on the surface tends to stay put and can't escape either into the air or the depths of the object.

I notice it most when laundry comes out of the dryer and is stuck together in one big static lump, but that doesn't happen every time. The majority of my clothes are made from cotton, except for my polyester sports kit. Static is worst are when both are mixed in together. This might be explained by something called the 'triboelectric series', which is an ordered list of materials telling you which ones get positively and negatively charged. If you rub together something on the 'positive' side (for example, glass) with something on the 'negative' side (for example, polyester), you're more likely to generate a strong charge. The problem is that the triboelectric series is only approximate – if you do the tests on a different day, you're quite likely to get a different order. Cotton is generally found around the middle of the triboelectric series and polyester is well into the negative end, setting me up for very clumpy laundry on days where I mix the two fabrics.

The thing that surprises me the most is that even the most recent research papers admit that no one is completely sure why this all happens, especially for a pairing like silk and a plastic comb. If you rub two metals together, everyone agrees that electrons hop across, and then the metal conducts the charge away. But if you rub two electrical insulators together, like silk and plastic, it's not that simple. The best current explanation seems to be that the friction generated by rubbing them together encourages small charged fragments of molecules (known as mobile ions) to jump the gap. The heat and the pressure between the rough surfaces may even cause chemical reactions which form those ions. But there's a lot of nuance, which is why it's hard to predict which way the charges will jump on any given day.

And silk? Silk is close to zero on most versions of the triboelectric series, next to cotton. Perhaps my scrap of shiny fabric would have been better off in a dress. Perhaps one day silk really will swoosh into science demos with some properly electric glamour.

Dr Helen Czerski is a physicist and BBC presenter. Her latest book is *Storm In A Teacup*.

NEXT ISSUE: ICE RAINBOWS

ILLUSTRATION: KYLE SMART

“I STILL REMEMBER THE DAY MY BRAIN BROKE”

Forget what you think you know about OCD. **James Lloyd** describes his battle with a devastating but little-known form of this mental disorder

ILLUSTRATIONS: SAM FALCONER

I was in a supermarket car park in Wales, in my early teens, on holiday at my grandparents'. It was a time of trips to the beach, limitless Welsh cakes, and peanut butter and jam sandwiches. But all was not well. Inside my head, a storm was brewing.

I'd had obsessive thoughts for as long as I could remember. As a child, I'd lie awake at night, worrying that the house was going to burn down, or that something terrible would happen to my family if I didn't go through my ritual of prayers. Once, I remember sitting in church, becoming gradually convinced that the man behind me was going to kill me.

But on this particular day, for no apparent reason, something shifted. A switch had been flicked inside my brain. There was white noise. I had become acutely aware of my own thought processes, and my head hurt. Like a million tiny birds pecking at the inside of my skull, my mind began to buzz with repetitive thoughts – thoughts that I'd do anything not to have. My brain had got stuck.

I didn't realise it back then, but this was the beginning of obsessive-compulsive disorder (OCD). A long way from the media stereotypes of someone with a neatly organised CD collection and immaculate sock drawers, I wouldn't get a diagnosis until I was in my 30s. In those intervening years, unable to explain what was going on in my own head, my mental health sank to depths that I didn't know existed. But it turns out that I wasn't alone. There's a whole world of people out there who are tortured by their thoughts, afraid to get help and unable to tell even their own families. This is what it's really like to live with OCD.

The average person has tens of thousands of thoughts a day. Most of these are fairly mundane, but given the sheer amount of chatter running through our brains, it's no surprise that we sometimes get strange, even disconcerting, thoughts that appear to come from nowhere. You're walking across a bridge and think of jumping off. You're cradling a baby and get an image of throwing her down the stairs. You enter a hushed cathedral and have the sudden urge to swear loudly.

Psychologists call these 'intrusive thoughts', and research has shown that everybody gets them. "When we asked people whether they experience these kinds of thoughts, 93 per cent said yes," says Prof Paul Salkovskis, professor of clinical psychology and applied science at the University of Bath. "In a follow-up study, we tried to interview those who said they didn't, and they didn't want to speak to us. I'm as convinced as it's possible to be that the real figure is 100 per cent."

Salkovskis believes we're hardwired to have these thoughts. "Intrusive

"Our ancient ancestor, when faced with a tiger, might have thoughts about running away, or trying to befriend it"

thoughts are our brain's way of dealing with uncertain circumstances, which we've had throughout our evolution," he says. "Thoughts will come into our minds that are loosely connected with what's going on around us – some of them will be good ideas, and some will be bad." According to this view, intrusive thoughts are part of our brain's in-built problem-solving system – a literal brainstorming mechanism that's designed to keep us alive. Just as our ancient ancestor, when faced with a tiger, might have thoughts about running away (good idea) or trying to befriend it (bad idea), so our brains today are constantly coming up with ideas to help us make sense of our surroundings – ideas which might be helpful, weird, or just downright scary.

Most people are able to dismiss the unhelpful intrusive thoughts as quickly as they arrive. But someone with OCD is unable to ignore them. They'll interpret them as saying something fundamental about who they are. What if I'm a danger to myself? What if I harm this baby? What if I'm evil?

BRAIN LOCK

It didn't take long for my OCD to snowball. In that car park, my brain began to fire obsessive thoughts at me about my sexuality. I started to constantly obsess over whether I was gay, to the extent that I was checking my attraction to every single person I saw. At this stage, I thought it was just me grappling with my sexuality, but by the time I was 20, things had got a lot darker.

My intrusive thoughts began to convince me that I was a horrible, evil person. I'd walk down the street, scared to meet people's eyes in case I had a terrible urge. If I was using a knife, I'd worry I'd suddenly lose control and stab someone. If I saw a serial killer in the news, I'd worry that I was going to turn into one. If I saw a kid in the street, I'd get intrusive thoughts that I was going to turn into a paedophile.

It was mental torture. OCD is known as the 'doubting disease' because it makes you question everything. It slowly erodes your sense of identity, and every waking hour becomes consumed with unwanted thoughts. I developed acute anxiety, depression and debilitating headaches. Even going to the shops became an ordeal, as just one intrusive thought could bring my anxiety to tipping point.

ILLUSTRATIONS: SAM FALCONER

"By trying to control my thoughts, I only made them worse. If someone tells you not to think of a pink elephant, you'll immediately have pink elephants stampeding through your head"

It was like living two lives at once, and there were days when I wanted to go to sleep and not wake up again.

For over 15 years, I was in the grip of OCD. But there are a lot of us out there. It affects an estimated 12 in every 1,000 people – that's almost 800,000 in the UK alone – but is often misunderstood as being a trivial personality quirk, or a penchant for order and cleanliness.

OCD can come in a number of guises, but it always follows the same pattern. First is the unwanted thought, image or urge. This is the 'obsessive' part of the disorder. OCD can attach itself to pretty much any theme, but common ones include thoughts about harm (either to yourself or others), suicide, disease, contamination, blasphemy, forbidden sexual thoughts, and relationship obsessions. The intrusive thought causes anxiety, so the sufferer feels compelled to do something to relieve it. This is the 'compulsive' part of the disorder, and it could involve washing, checking, counting, repeating a phrase, praying, going over things in your mind, or a whole host of other coping mechanisms. These behaviours can be physical or (as in my case) purely internal, invisible to everyone except the sufferer. This internalised form of OCD is often called 'Pure-O' (purely obsessional OCD), but this is something of a misnomer, as compulsions are still involved – they're just going on beneath the surface.

Once a compulsion is carried out, it will only have a temporary effect. Soon enough, another thought or trigger will occur, and the compulsions will ramp up again as the sufferer attempts to calm the anxiety. It's a vicious loop, and one which can easily mushroom out of control. It's no surprise that OCD sufferers are 10 times more likely to take their own life.

I developed a number of ways to cope with my anxiety. All day, every day, I'd monitor my thoughts. If I had one that I deemed 'bad', I'd immediately have to think of a 'good' one to counteract it, or I'd wrestle with the thought until I was sure it didn't mean anything. I'd monitor my facial expressions in case I somehow developed an 'evil face', and I wouldn't be satisfied until everything in my head felt 'just right'. But by trying to control my thoughts, I only made them worse. If someone tells you not to think of a pink elephant, you'll immediately have pink elephants stampeding through your head.

OCD is a shape-shifting beast. As I found out, the themes can evolve over time, and they often latch on to whatever the sufferer holds most dear. The new mother has an image of harming her baby. The priest thinks of blasphemy. Zoom out, though, and interesting patterns begin to emerge.

"When I started working with patients in 1977, no one had intrusive thoughts about contracting HIV/AIDS," says Salkovskis, "but then in the 1980s that became a common theme. OCD is often centred around whatever is society's 'invisible threat'. Today, intrusive thoughts about being a paedophile are common. A few hundred years ago, most of the thoughts would probably have revolved around religion."

Salkovskis is keen to stress that people with OCD pose no danger. "There is absolutely no record of anyone with OCD acting on their obsessional thoughts," he says. "The thoughts are completely at odds with the person's values." He offers an example of a therapy exercise he used to carry out with people who experienced intrusive thoughts about harming others. "I used to keep a sharp kitchen knife in my drawer, and I'd ask the person to hold it to my neck. I'm still here!"

ALWAYS HOPE

I was formally diagnosed with OCD last year, and I've recently finished a course of cognitive behavioural therapy (CBT). This talking therapy is the go-to treatment for OCD, sometimes in conjunction with anti-anxiety medication, and it involves helping sufferers to see their intrusive thoughts for what they are – meaningless brain piffle. In my case, it involved a technique called 'exposure and response prevention' (ERP), in which I had to write out scripts of my most feared thoughts and learn to tolerate the anxiety without performing any compulsions. The idea is to accept and embrace the thoughts, until you're so used to them that they no longer cause anxiety.

I sometimes wonder whether I was destined to develop OCD. Did something go wrong in my brain's wiring as I was growing up? There's certainly evidence that the OCD brain is firing differently.

ILLUSTRATIONS: SAM FALCONER

"In people with OCD it seems that a neural loop between these regions becomes hyperactive, which neuroscientists think is linked to the repetitive thoughts and behaviours"

Research points to the relationship between three brain areas: the prefrontal cortex, striatum and thalamus. With OCD, it seems that a neural loop between these regions becomes hyperactive, which neuroscientists think is linked to the repetitive thoughts and behaviours.

But it's difficult to know whether these brain differences are the cause or the consequence of the OCD. And it's likely that a number of other factors play a role. OCD is often linked to 'thinking errors' in the way someone sees the world. These cognitive distortions, which can begin to form in childhood, might include an inflated sense of responsibility ("I must not upset anyone at all."), a desire for 100 per cent certainty ("how can I be certain my partner loves me?"), or the belief that having a nasty thought is as 'bad' as acting on it ("I'd be locked up if people knew what I was thinking.").

OCD can also be triggered by a traumatic event, and there's likely to be a genetic component, too. A 2011 meta-analysis looked at 14 separate studies involving identical and non-identical twins, designed to tease apart the contribution of genetic and environmental factors in someone developing OCD. Genetics was found to account for around 40 per cent of the variance in OCD behaviour, with the remaining variation down to environmental factors.

However my OCD started, I still have it. But I'm beginning to see the light through the fog. I still get intrusive thoughts, but I'm getting better at letting them go. It took me years to find help, and that's not uncommon. In fact, there's so much stigma and misunderstanding around OCD that the average person goes 12 years between the onset of their illness and being diagnosed. That has to change.

There are sure to be a lot of people suffering in silence, especially with the purely internalised form of the disorder. "People with this type of OCD can get away with it not being noticed," says Salkovskis. "Tormented though they might be, they can go for longer before they hit the crisis point."

For Christmas, I'd like a time machine. My first stop will be that supermarket car park in Wales, and I'll give that kid just one piece of advice: there's no such thing as a bad thought. And then I'll let him know that he'll be okay. It won't be easy, but he'll be okay.

James Lloyd is a science writer and editorial assistant at *BBC Focus*.

DISCOVER MORE

OCD Awareness Week is 8-14 October 2017. For more information, help and support, visit **ocduk.org**

To read the thoughts and experiences of people with OCD, visit **thesecretillness.com**

5 MYTHS ABOUT OCD

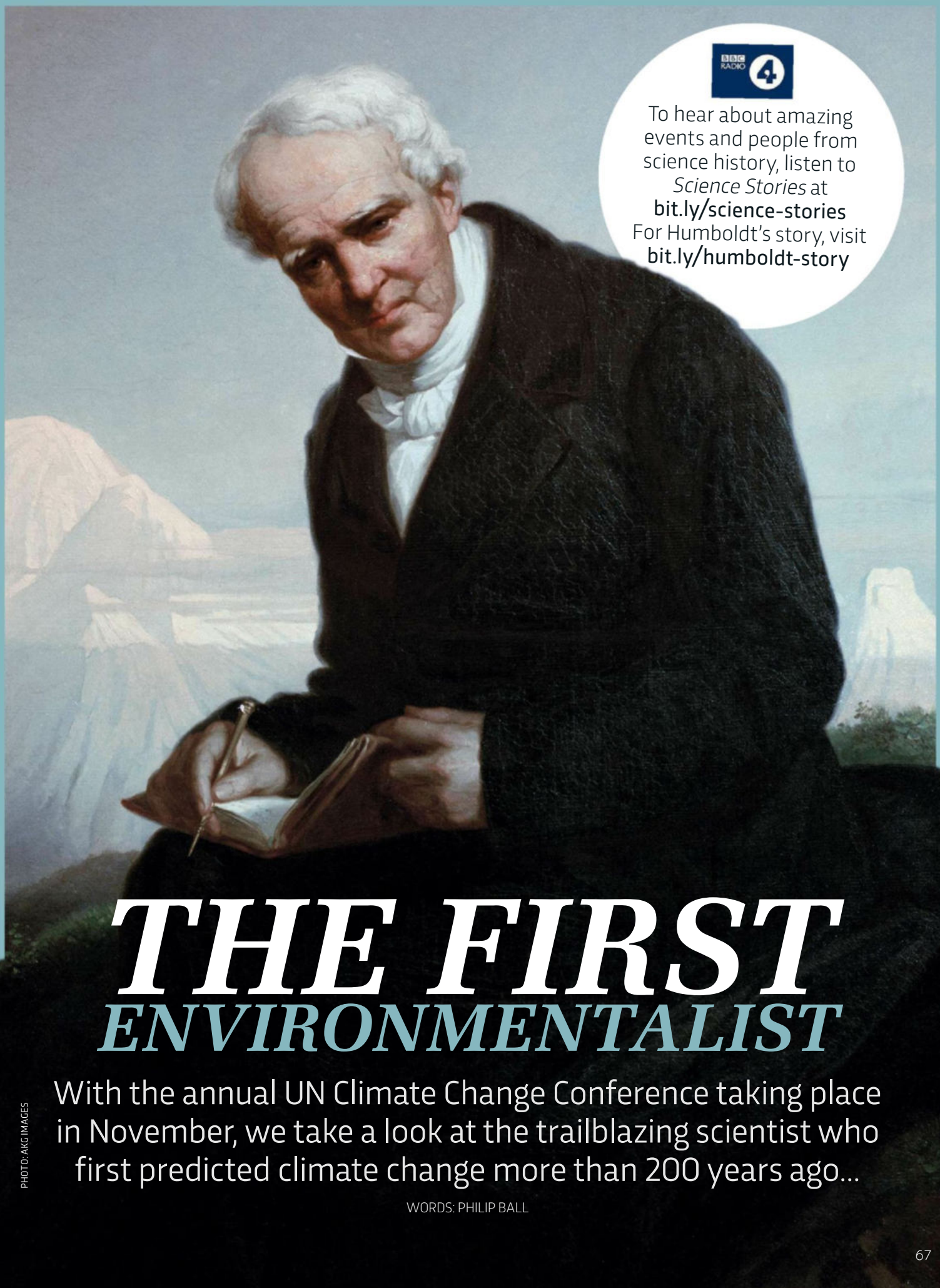
1 People with OCD wash their hands a lot
Repetitive handwashing is one of the most well-known forms of OCD compulsion, but it only affects around one-quarter of sufferers. Similarly, compulsive checking (taps, locks, light switches, for example) affects around 30 per cent of sufferers.

2 People with OCD are neat freaks
Often confused with a liking for order and neatness, OCD is an anxiety disorder, characterised by frequent, distressing, and unwanted thoughts. A need for order or symmetry *can* sometimes arise, but this will be driven by an unbearable, underlying anxiety.

3 OCD always involves repetitive actions
Not all OCD compulsions are visible. Around a quarter of OCD sufferers carry out covert, internalised compulsions. These might include praying, suppressing or neutralising thoughts, counting, and avoiding certain situations and places.

4 Having OCD can be a useful thing
There is no joy in OCD. The World Health Organization once ranked it as one of the ten most debilitating illnesses of any kind, in terms of lost earnings and diminished quality of life. At least one-third of people with OCD also suffer from depression.

5 OCD only affects adults
The average age of onset is 20, but OCD can also affect adolescents, as well as children as young as four. Making a diagnosis at this early age is especially tricky, as repetitive behaviours can also be a completely normal part of child development.



To hear about amazing events and people from science history, listen to *Science Stories* at **bit.ly/science-stories**
For Humboldt's story, visit **bit.ly/humboldt-story**

THE FIRST ENVIRONMENTALIST

With the annual UN Climate Change Conference taking place in November, we take a look at the trailblazing scientist who first predicted climate change more than 200 years ago...

WORDS: PHILIP BALL

PHOTO: AKG IMAGES

Back in the early 19th Century, Alexander von Humboldt, a German naturalist and explorer, warned that humans had the power to upset the delicate balance of nature. While we are familiar with this concept today, the idea was completely radical at the time, because for centuries it had been presumed that nature was explicitly created for our benefit and use. While trekking through the rainforests of South America, Humboldt had witnessed first-hand how human destructiveness could wreak potentially irreversible havoc with natural ecosystems and climate. And it was during his travels that he began to appreciate both the interconnectedness of life and humankind's capacity for destroying it. Humboldt said that nature had its own laws, and it is the duty and responsibility of humans to discover them, because otherwise we risk doing catastrophic harm. These were remarkably prescient observations, and ones which echo through to our current thinking around deforestation and climate change. Yet few people have heard of him.

OBSERVATION AND IMAGINATION

Humboldt's story reads like a romantic adventure. He braved alligators, giant spiders, jaguars and vicious insects to explore the South American jungles and savanna. He climbed the mountains of the Andes and went down into the mines of Mexico. He rode with Cossacks through the steppes of Central Asia to the Mongolian border. He met Napoleon Bonaparte (who hated him), and he befriended Thomas Jefferson and the Venezuelan revolutionary leader Simón Bolívar, liberator of northern South America from Spanish rule.

But there's more to this story than romantic derring-do. Humboldt wanted to make sense of all he saw. With his lifelong friend, the German poet and natural philosopher Johann Wolfgang von Goethe, Humboldt shared the view that nature might be understood not as a catalogue of wonders, but as a unified whole: a puzzle that could be decoded through careful observation and measurement combined with imagination.

He was a key inspiration for Charles Darwin. "Nothing ever stimulated my zeal so much, as reading Humboldt's [travelogue] *Personal Narrative*," Darwin wrote. Darwin's vision of nature has come to be seen as one shaped by fierce competition in the struggle for survival. Humboldt's conception of nature, in contrast, invoked balance and harmony: an integrated whole arising from the interplay of countless elements in the living and non-living worlds.

Deforestation of the Amazon is a concern because the rainforest has a vital role in absorbing carbon – the trees keep the planet healthy. Here, rainforest near Santarém in Brazil has been cleared to make way for a soy plantation

PHOTOS: GETTY, AKG IMAGES

In 1856, artist Eduard Hildebrandt painted this watercolour of Humboldt in his extensive library, filled with haphazard piles of books and documents

This picture of mutual interaction and sympathy resonates today among scientists who study the way the planet works. In this grand vision, the atmosphere, oceans, land masses, deep volcanic depths, plants, animals and microscopic life all play a part. But as Humboldt warned us two centuries ago, the balance can be lost – and we can be the cause.

STRANGE NEW WORLD

Humboldt was born in 1769 to an aristocratic family who owned an estate near Berlin in Prussia, an historical German state. His father was an army officer and a royal official, while his godfather was the future Prussian king, Friedrich Wilhelm II.

Privileged and good-looking, Humboldt was also prone to melancholy and self-doubt. He was lonely and filled with a lust for knowledge and travel. He studied economics at Hamburg and then mining in Freiberg. His family hoped he would pursue that subject as a business, but Humboldt insisted on getting his hands dirty, going down the mines to examine the minerals and geology. In the evenings he studied natural sciences, botany and electricity.

"He braved alligators, giant spiders, jaguars and vicious insects to explore the South American jungles and savanna"

The young Humboldt was desperate to go out and explore the world. In 1799 he and his friend, the French naturalist Aimé Bonpland, were granted passage to the Spanish colonies in the New World, and in June they set sail on the frigate *Pizarro*, named after the conquistador who had ruthlessly crushed the South American empire of the Incas.

Humboldt had amassed a collection of instruments: telescopes, microscopes, clocks, compasses, all carefully packed in padded cases. "My head is dizzy with joy," he wrote. It took the two men six weeks to cross the Atlantic Ocean and land in New Andalusia, today part of Venezuela. Over the next five years Humboldt journeyed in what is now Colombia, Ecuador and Peru, as well as Mexico, Cuba and the United States. ●

Everything was new, strange and exciting. There were spiders that ate hummingbirds, gigantic snakes, electric eels that could shock a person to death, monkeys, toucans and gloriously plumed macaws. He and Bonpland climbed the Andes, braving precarious paths, thunderstorms and blizzards. In 1802 Humboldt ascended the volcanic Mount Chimborazo, the highest mountain in Ecuador, with its snowy peak about 6,268m above sea level. Despite suffering from altitude sickness and struggling against freezing winds, Humboldt took readings of temperature, air pressure and humidity.

In the Andes he noticed similarities with the plants and rocks of the Alps, and, looking down at the world from the high slopes, he began to sense patterns and connections in the great web of life. Here he started to develop his great vision. "Nature," he wrote, "is a living whole."

NATURE'S TAPESTRY

The living world is a kind of tapestry, Humboldt concluded, that embraces everything from moss to macaws. He could hear it in the cacophony of animal noises that pierced the night in the rainforests, a chain reaction of cause and effect. Humboldt felt that all of this was a contest, with survival at stake. This insight was on the brink of Darwin's idea that competition among species is what drives evolutionary change. Nature was no Garden of Eden exquisitely designed by God. It could be a brutal place – in balance, yes, but a balance maintained only by fierce struggle.

And that equilibrium is precarious, thought Humboldt. Pull one thread and the whole tapestry might unravel. Nature's strands are intimately woven, but humankind can undo them. Humboldt saw this particularly in the plantations around Lake Valencia in what is today northern Venezuela. The felling of trees by settlers did more than just denude the landscape.

"When forests are destroyed, the springs are entirely dried up," he wrote. "The beds of the rivers are converted into torrents whenever great rains fall on the heights… They furrow during heavy showers the sides of the hills, bear down the loosened soil, and form those sudden inundations that devastate the country."

Trees, soil, climate and life – it's all connected, Humboldt realised.

The notion that humans might have a negative impact on climate and landscape wasn't widely perceived at the time. The majority of people saw the cultivation, settlement and taming of 'wilderness' as an unalloyed good: an improvement on

Mount Chimborazo, ascended by Humboldt, is the highest mountain in the world, if measured from the centre of the Earth rather than from sea level. This is because Chimborazo is close to the equator, where the planet bulges

PHOTOS: GETTY X7, ALAMY, AKG IMAGES

THE CHANGING FACE OF THE AMAZON

1799–1803 Alexander von Humboldt journeys through northern and western South America, making extensive observations of the wildlife, geology and climate.

1845 Publication of the first volume of Humboldt's *Kosmos*, which describes nature as a unified and interdependent system encompassing the living world, the geological world, the rivers, oceans and atmosphere.

1849 English botanist Richard Spruce begins his exploration of the flora of the Amazon and Andes, later described in the posthumous *Notes Of A Botanist On The Amazon And Andes* (1908).

1934 Brazil approves the first Forest Code to recognise the need to conserve forests and natural ecosystems, stating that the rainforests are "of interest common to all inhabitants of the country."

The Earthrise image was taken on Christmas Eve 1968, during the first manned mission to the Moon. Humboldt's biographer Andrea Wulf suspects it was this image that finally made us recognise the delicate nature of our planet

the chaos of the wild. But in fact, the effect could be devastating. In Mexico, Humboldt saw that irrigation for farming could deplete natural rivers and lakes; off the coast of Venezuela, pearl fishing had decimated oyster stocks; mining had despoiled the land. The arrogant assumption that nature was there for us to exploit could be its undoing.

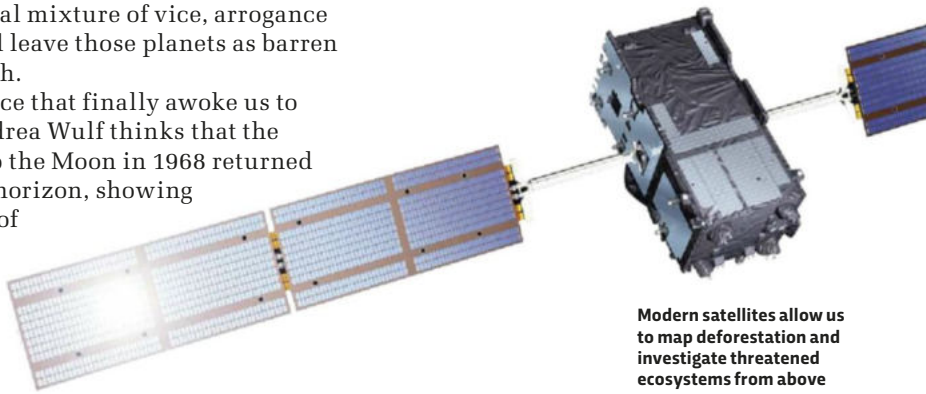
THE WIDER VIEW

It was a cosmic responsibility. One day, Humboldt speculated in 1801, we might travel to distant planets – and we will take our "lethal mixture of vice, arrogance and ignorance with us". He suspected that we would leave those planets as barren and as ravaged as we have already done here on Earth.

Perhaps it was our first tentative ventures into space that finally awoke us to Humboldt's cautionary message. His biographer Andrea Wulf thinks that the moment of change was when the Apollo 8 mission to the Moon in 1968 returned with the now iconic Earthrise image over the lunar horizon, showing our blue and white planet against the dark vastness of space. It was an epiphany akin to the one Humboldt experienced atop Mount Chimborazo. The world needs to be experienced and understood on many scales: you must get down amidst the plants and soil with your measuring devices, but you must also seek a grand vantage point.

Today, satellites in Earth orbit provide that broader perspective. Thanks to their observations – and the work of scientists in the field – we now know that rainforests, in the Amazon basin and beyond, are one of the most threatened ecosystems in the world. In the past 25 years alone there has been a 10 per cent decrease globally in the area of tropical rainforest due to human activities. There are also thought to be tens of thousands of plant species still undiscovered in the world's rainforests, some of which could be sources of valuable new medicines – if they can be found before they go extinct.

We can see today how prophetic Humboldt was, because destruction of the rainforests has been shown to have consequences for the local ➤



Modern satellites allow us to map deforestation and investigate threatened ecosystems from above

1960s Settlement and development in the Amazon sees the start of deforestation by slash-and-burn cultivation of land.

1972 Construction begins on the Trans-Amazonian highway. Although only part of the highway is constructed, it accelerates deforestation by giving loggers easy access to the rainforest.

1990s Environmental scientists warn that deforestation can have a significant impact on climate change, reducing the natural 'carbon sink' that absorbs atmospheric carbon dioxide.

2004 The Brazilian government introduces the Action Plan for Prevention and Control of Deforestation in the Legal Amazon, seen as a turning point in controlling Amazon deforestation.

2007 The Intergovernmental Panel on Climate Change warns that "up to 40 per cent of the Amazonian forests could react drastically to even a slight reduction in precipitation." Droughts in the Amazon in 2010-15 cause major tree death.

Humboldt's travels in South America, 1799-1803

1 **July 1799** Arrives with Aimé Bonpland in Cumaná, Venezuela.

2 **November 1799** Witnesses an earthquake in Cumaná.

3 **February 1800** Observes how deforestation around Lake Valencia in Venezuela increases soil erosion by rain, and how trees maintain air humidity.

4 **March 1800** Observes electric eels attacking wild horses in the Los Llanos grasslands, and studies how they generate their shocks.

5 **March-July 1800** Travels down the Orinoco River. Describes the deadly poison curare, the first European to do so, and is almost killed when he touches it.

6 7 8 **Late 1800-1801** Travels via Cuba to Cartagena and Bogotá in New Granada.

9 **September 1801** Crosses the Andes from Bogotá to Quito along the treacherous Quindío Pass, braving thunderstorms and blizzards.

10 **Early 1802** Investigates volcanoes of the Andes such as Pichincha, near Quito.

11 **June 1802** Ascends Mount Chimborazo, a 6,268m-tall volcano in present-day Ecuador. After his descent, Humboldt begins to sketch an illustrated cross-section of the volcano.

12 **October 1802** Arrives in Lima, Peru.

13 **February 1803** Leaves South America from Guayaquil in New Granada, bound for Mexico.

Even today, botanists are still finding incredible new species of plants in the Amazon

PHOTO: ALAMY ILLUSTRATION: MARTIN SANDERS/MAPART.CO.UK

"Perhaps it began to seem that creation was more awe-inspiring, more worthy of devotion, than the notion of a creator"

environment and the planet as a whole. Rainforests not only help to maintain the moist climate that supports such a bountiful variety of life, but they're also vital to the regulation of the Earth's climate.

As they grow, tropical rainforests absorb large quantities of the greenhouse gas carbon dioxide from the atmosphere. Collectively, they suck up around 2.4 billion tonnes of carbon each year; the Amazon rainforests alone are responsible for abosorbing a quarter of that. But a 2015 study found that on average, Amazon forests absorb carbon today at a rate at least one-third lower than they did in the 1990s. This seems to be due to a greater rate of tree death, partly because of the serious droughts of 2005 and 2010 but also because the higher carbon dioxide concentration in the air encourages trees to grow faster but less robustly. And that's before we even take into account the loss of carbon uptake because of deforestation itself. If the rainforests suffer, we all suffer.

A FINAL CHAPTER

As for Humboldt, he didn't stop with the Americas. After establishing himself as one of the most distinguished German scientists of his age, in 1829 he embarked on another daring and perilous expedition: across Russia and Central Asia, through Siberia and all the way to the Mongolian border. Humboldt was then 59 years old, but he astonished his retinue with his vitality, climbing mountains and crawling into caves. He returned with more plants, rocks, measurements – and ideas.

In the later years of his life, he put them all together in a grand synthesis, a work called *Kosmos* that sprawled over five volumes and gave an account of all of creation, from the stars and planets to volcanoes, auroras, rocks, plants, insects and algae. Nothing like it had been attempted before, and it inspired generations of scientists, artists and writers.

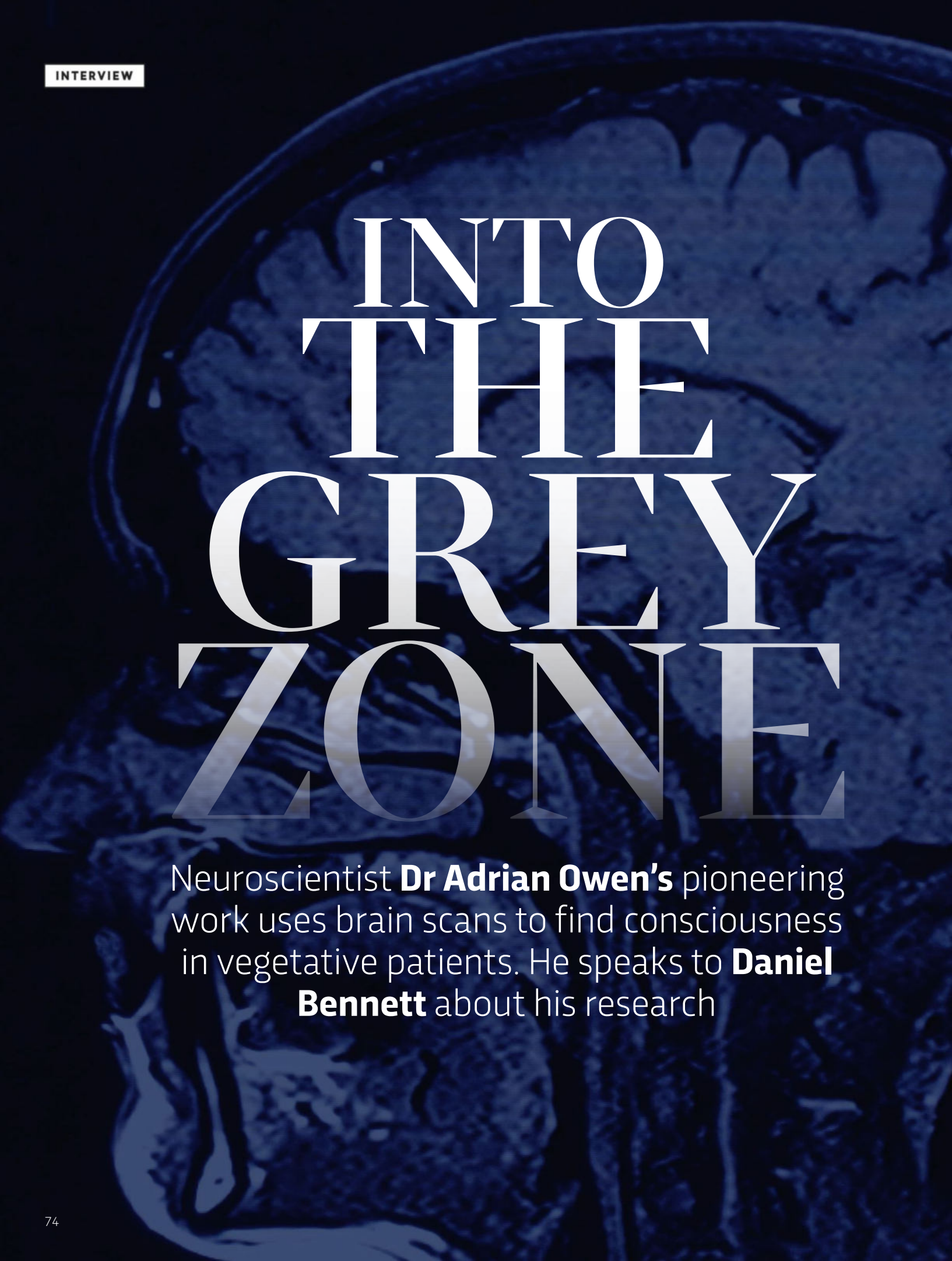
Kosmos spoke about nature as a "living whole", and a "wonderful web of organic life". And nowhere in this work, astonishingly for the time, did Humboldt feel the need to mention God. With so much to wonder at in nature itself, all part of a rational and comprehensible scheme of organisation, perhaps it began to seem that creation was more awe-inspiring, more worthy of devotion, than the notion of a creator.

When Darwin wrote that "there is grandeur in this view of life," he wasn't just talking about evolution by natural selection, but about the rich interplay of a planet and its inhabitants that Humboldt had identified. Preserving those riches is now down to us. If we fail, it will not just be a breakdown of planetary responsibility and of rational self-interest. It will also be a failure of imagination.

Philip Ball is a science writer and presenter of *Science Stories* on BBC Radio 4. His latest book is *Patterns In Nature: Why The Natural World Looks The Way It Does* (£19.95, University of Chicago Press).

DISCOVER MORE

Andrea Wulf's biography of Humboldt *The Invention Of Nature* was the winner of the 2016 Royal Society Books Prize (£10.99, John Murray).



INTO THE GREY ZONE

Neuroscientist **Dr Adrian Owen's** pioneering work uses brain scans to find consciousness in vegetative patients. He speaks to **Daniel Bennett** about his research

What is the 'Grey Zone'?
It's a term I coined to describe a state between being completely awake and aware of who and where you are, and at the other end of the spectrum, a state where you're completely unaware of anything. In my work, this typically means patients in a vegetative state – but it could mean something more familiar, like being under a general anaesthetic.

What typically leaves a patient in this state?
I'm interested in any patient who's had a serious brain injury, and that's two groups: traumatic and non-traumatic injuries. Traumatic injuries typically involve a blow to the head, often in some kind of vehicle accident. But a non-traumatic brain injury might also put you into a vegetative state. That might be an anoxic injury – where the brain is starved of oxygen, as can occur in near-drowning accidents – or a stroke.

What does it feel like to be in the Grey Zone?
Every patient is different. What does it feel like to have your sense of being a person gradually deteriorate to the point that you become detached to the outside world? We're starting to decode what it's like to be minimally conscious, but we still don't know. Every patient who's recovered – and they're rare – has something a little different to say.

Kate, my first patient, described quite harrowing experiences. She talked about a raging thirst that she couldn't alleviate, and at one point she wished she could die. Another patient who made a spectacular recovery was optimistic: he said he always knew that he was going to get out.

How have we viewed patients like this in the past?
When we came into this area 20 years ago, the assumption was that these patients were all the same: they were in a vegetative state with no sense of who or where they were. But through many brain imaging studies over the last 20 years, we've shown that what you see is often *not* what you get.
A recent study reported that one in five patients reported as vegetative seem to have some level of awareness.

On the surface, some patients that may not appear to be entirely responsive may be somewhere in there. That consciousness can take many different forms. It could mean that the patient can understand a little bit of what's going on around them, to full-blown conscious awareness where a patient is trapped inside their head, unable to respond but aware of everything going on around them and every decision made on their behalf. Sometimes they're in that situation for decades.

Where did your research into the Grey Zone start?
I was at working in the Wolfson Brain Imaging Centre at Addenbrookes Hospital in Cambridge, and a colleague brought a patient called Kate to my attention. He said a virus had attacked her brain.

"One in five patients reported as vegetative seem to have some level of awareness"

Dr Owen's research has shed new light on the experiences of people in vegetative states

PHOTO: GETTY

"It was a shock when Kate's brain responded to the faces in the same way our own brains might"

The two of us cooked up the idea of putting her into the brain scanner – in those days it was known as Positron Emission Tomography or PET scanning. We did it not knowing what the outcome was going to be. Everybody assumed that none of these patients would produce any brain activity in response to stimulation.

We showed her pictures of her friends and family, because I'd been doing some work on face recognition: mapping which parts of the brain were involved in processing faces. We thought if we showed these to Kate, and if there was anything going on in her brain, the part of it involved in recognising faces might light up. We all expected nothing to happen, so it was a shock when Kate's brain responded to the faces in the same way our own brains might. The fact that Kate's brain sprung into life that day really laid the foundation for everything that came afterwards.

Where did you go from there?

In the decade that followed, we started putting together the building blocks of consciousness. We kept trying different things to see whether some patients would respond to them. To some we showed faces, to others we played speech, and the answer at every stage was 'yes'. We'd find a patient who was responsive, but each time we were stuck with this question: does it mean that they are conscious? Maybe the patients' brains were on autopilot. Maybe their brains were just automatically processing language and faces, because these are things we have very little control over.

So I asked the question – and this was really my big 'a-ha!' moment – "What would you have to do to be absolutely sure a patient is conscious?". I realised that you have to go back and think about that scenario that everyone has seen in a medical drama, where the doctor holds the patient's hand and says, "Squeeze my hand if you can hear me." If you say that to a patient and they do it, you know they understand language, you know they can initiate an action; essentially, you know they have some level of awareness. I realised that we had to do the same thing with brain scanning. We had to measure a pattern of brain activity that could not be automatic.

So you asked them to play tennis...

It sounds a bit bizarre, I know, but it's just a way to get patients to do what we want, which is to imagine moving their arms around. This action activates a part of the brain called the premotor cortex, which is involved in planning and initiating movements. If you think about waving your arms around, the premotor cortex will light up: even if you don't physically move, simply *thinking* about tennis activates the areas involved. If we could get a patient to activate their premotor cortex when we asked them to do so, I knew at that point we would know they were conscious.

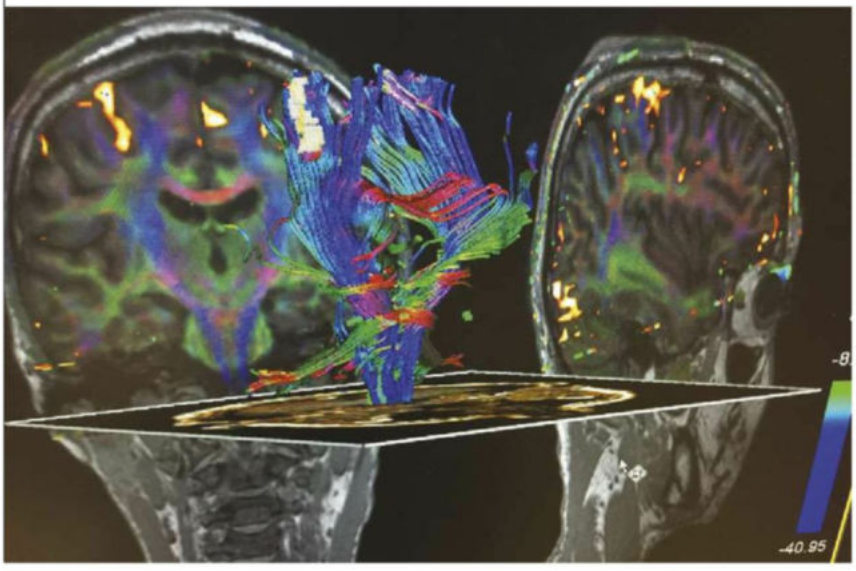
So tennis gave you a way to talk to people. How did that work?

We had this signal now, so we could then use that as a response. We'd say to patients: "I'm going to ask you a question. If the answer is yes, please imagine playing tennis." We'd start with simple questions like "Is your name Dan?" and we'd see activity and we knew we'd got a yes. And of course we'd have another signal for no. Then we'd go on to stuff like asking them if they were in pain, or whether they were afraid, and we'd get answers out of patients who were entirely physically non-responsive.

What do you do once you find out they're conscious, but effectively trapped. What if they say they're in pain? What would happen next?

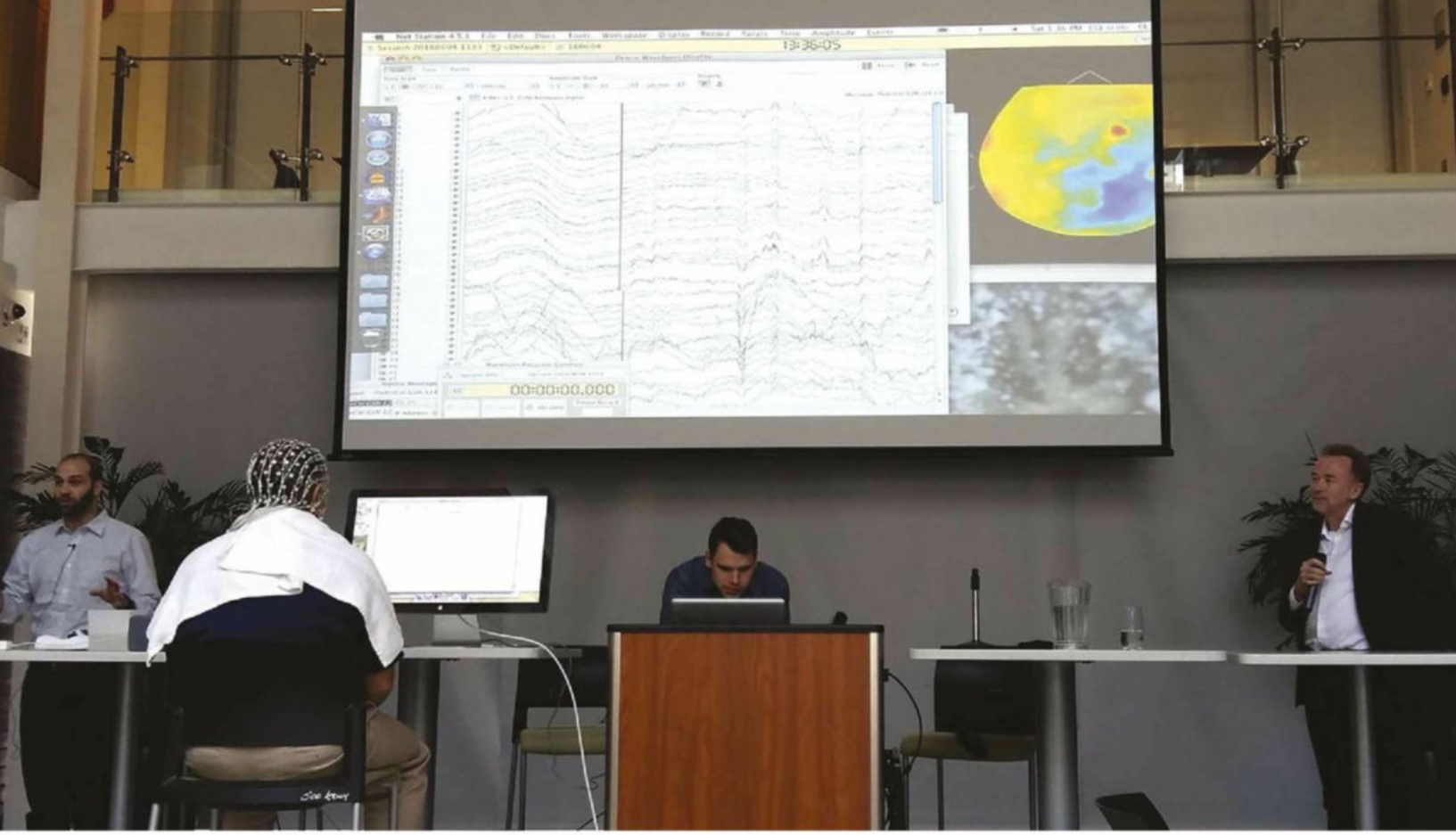
This is exactly why I wrote this book. We don't have this end idea that we work toward until we get there – the whole thing is an evolving process and I can honestly say that, over the 20 years the book covers, I had no idea at the beginning of the journey where it would end up. Indeed, I'm not at the end now, I'm still continuing with this work. I never know what I'm going to find.

One thing that gets us into hot water is when we have a patient in the scanner and they're answering yes and no, and we've asked all the questions we've thought of. What do we do next? Sometimes we're flying by the seat of our pants, and it can bring us quite close to complexities with our ethics committees because we want to do things we don't



Dr Owen's research involves using an fMRI scanner to track activity in the brain – specifically, activity in the premotor cortex

PHOTO: WESTERN UNIVERSITY LONDON CANADA



Dr Owen gives a demonstration of his methods at a meeting of the Canadian Science Writers' Association in 2016

have permission to do. Not because we're not allowed, but because we didn't know just how far we'd get. Suddenly we're thinking, 'Should we ask this patient if they want to live or die?'

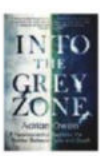
What effect did 'finding' these patients have?
Kate, my first patient, told me that the scan "found her". In her own words she said the day we scanned her she became a person again. Now, after 20 years working with these patients, I know exactly what she means. It's very difficult to maintain a sense of a person being somebody when they're totally non-responsive. These patients don't respond, they don't appear to be listening when you talk to them, or when you play them music. It's human nature. It becomes difficult to remember that that person has a personality, attitudes, beliefs and love. Things they like and don't like. The moment you identify that somebody is in there, they become a person again. They have hopes for the future.

What about for the patients – does the act of contact help them?
We know what happens to people in solitary confinement. We know there are benefits of social interaction. Suddenly when we 'find' a patient they get a cascade of attention because their relatives, nurses and often the media become interested in them and they pay them a lot of attention. I'm always careful with this idea, because I'm crossing what is scientifically backed up. But it's tempting to wonder if this has contributed to improvements.

Where does your work go next?
Now, we're communicating on a fairly regular basis with patients in the scanner. Often what happens is that families want to ask more, but we can't because MRI is expensive, and it's not portable. It's not very convenient. This has pushed me to try and find a way to send somebody home with a piece of technology that will allow these patients to communicate with the outside world for the rest of their life. I don't think it's a long way off.

There's a number of technologies we're exploring. There's a promising technique known as functional near infrared spectroscopy that looks at oxygenated blood in the scalp to understand how active the brain is being; in a sense it's quite similar to MRI, and it can be miniaturised. You simply point the device at the area you're aiming to activate and see if it gives you a response. It's terribly efficient and fast. The work isn't published yet, but we were recently able to communicate with a non-responsive patient with this method.

The book is quite harrowing at times. Has your work affected your own life?
I do think a lot about these people – it's been very important for me, getting to know them. Getting to know their lives and them getting to know mine. As a PhD student I would test and see patients, but I was detached from them as people. My focus was on the scientific question. But now I'm very much more involved in the patients' and the families' lives, which personally is much more satisfying.



Into The Grey Zone is on sale now and available in all good book stores. Visit **intothegrayzone.com** for more. You can see Dr Owen speak at the Manchester Science Festival on 26 October: details at **manchestersciencefestival.com**

BBC Focus Magazine Reader Survey

Let us know what you think **for a chance to win a £250 Amazon Voucher!**

Would you like to have your say in the development of BBC Focus Magazine?

Every year, we carry out research on behalf of BBC Worldwide that invites readers to share their views about this magazine and other BBC Worldwide titles.

This essential research is used by BBC Worldwide and the editors to shape future content and strategy for the magazines. We would really appreciate your time to help us with this research.

To take part in the research and be entered into a prize draw to win a £250 Amazon Voucher, please visit:

bbcworldwide.com/survey

The survey will take less than 10 minutes and is being conducted according to Market Research Society guidelines. All of your responses are completely confidential.

Terms and conditions: The prize is one £250 Amazon Voucher. One winner will be drawn at random after the closing date at 23.59 on 31st December 2017. Open to all residents of the UK and the Channel Islands aged 18 years or over except employees of BBC Worldwide or the BBC, their contractors, members of their families and anyone connected with this prize draw. Only one entry permitted per person. There is no cash alternative and the prize is not transferable. No purchase necessary. The prize draw is subject to the laws of England and Wales. Promoter: BBC Worldwide Limited, Television Centre, 101 Wood Lane, London W12 7FA. Your data will be used for the purposes of administration of this prize draw and in accordance with BBC Worldwide's Privacy Policy (www.bbcworldwide.com/privacy.aspx). Where consent has been provided, BBC Worldwide may send email marketing messages from which you may unsubscribe at any time.

BBC FOCUS MAGAZINE


DR ALASTAIR GUNN
Astronomer, astrophysicist


ALEX FRANKLIN-CHEUNG
Environment/ climate expert


DR PETER J BENTLEY
Computer scientist, author


PROF ALICE GREGORY
Psychologist, sleep expert


PROF MARK LORCH
Chemist, science writer


CHARLOTTE CORNEY
Zoo director, conservationist


DR HELEN SCALES
Oceans expert, science writer


DR CHRISTIAN JARRETT
Neuroscientist, science writer


EMMA DAVIES
Heath expert, science writer


LUIS VILLAZON
Science/tech writer


DR AARATHI PRASAD
Biologist, geneticist


PROF ROBERT MATTHEWS
Physicist, science writer

YOUR QUESTIONS ANSWERED

OCTOBER 2017 | EDITED BY EMMA BAYLEY

Are floating solar farms better than land-based ones?

TANIA SMITH, LEDBURY

Where land is scarce, floating solar farms make it possible to generate renewable energy without taking up space that might be needed for farming or other purposes. The cooling effect of the water allows the floating solar cells to run more efficiently than on land. Most floating solar farms are installed on artificial lakes or reservoirs. For example, the world's largest floating solar farm, recently unveiled in China near the city of Huainan, sits on top of a former coal mining area that has been flooded. By covering the water's surface, floating solar farms reduce evaporation, saving water. **AFC**

PHOTO: EVEVINE

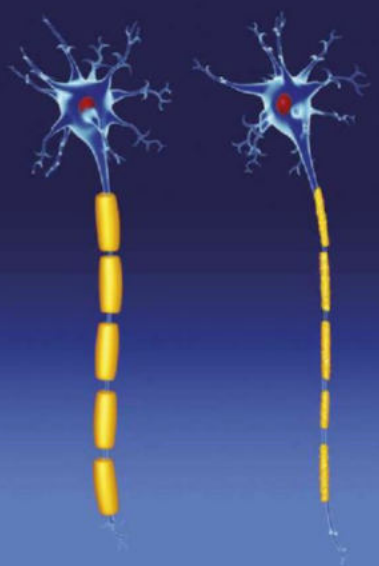
Why can't penguins fly?

SALLY THOMPSON, BURNLEY

Even the very smallest penguin, the fairy penguin, weighs 1kg, which is about as much as a herring gull. But herring gulls have a 1.4m wingspan, compared with just 32cm for the fairy penguin. Water is 784 times denser than air, and around 62 million years ago, penguins began evolving adaptations for swimming underwater. Their bones are filled with heavy bone marrow rather than air and they have much larger stomachs for undergoing long fishing trips away from the nest. **LV**

Can the body self-repair nerve damage?

BRIAN SHIMELL, SURREY



The myelin sheath (yellow) on a nerve cell increases the speed at which nerve impulses travel. Here, the myelin of the nerve cell on the right has become damaged

Up to a point. If the body of the neuron is still intact, the branches that extend out from the cell body can regrow at a rate of about 2cm per month. If the surrounding membrane of a nerve bundle is still intact, the neuron can grow along this, to its original target. But muscle cells left disconnected for too long won't accept new nerve connections. LV

Is gravity getting weaker?

TIM FARROW, PRESTON

Over the years, theorists have proposed modification to Einstein's theory of gravity that allow this fundamental force to vary with time. In the 1930s, the eminent British physicist Paul Dirac suggested that gravity might get weaker as the Universe expanded, prompting astronomers to look for evidence. During the 1970s, studies of the Moon suggested it was moving away from the Earth. Most of the increase in distance could be explained using standard theories of how the gravity fields of the Moon and Earth interact. But some of the increase pointed to a weakening of the force of gravity itself, as Dirac had predicted. The claim attracted a lot of media interest, but by the early 1980s experiments involving precise timing of signals from planetary probes found no evidence for changes in the strength of gravity. The original claim is now thought to be the result of faulty analysis of the Moon's orbital motion. RM

Why are most passenger planes painted white?

TERRY FAIRHALL, BY EMAIL

The main reason is that it protects the aircraft from the effects of solar radiation. Aircraft struggle to stay cool while loading and unloading passengers at airports in hot countries, and brilliant white paint helps bounce back some of the sunlight. It also helps protect aircraft parts made out of composite materials from damage through ultraviolet radiation, which is substantially higher at altitude. **RM**

Do other planets influence Earth's tides?

SAMUEL JONES, MANCHESTER

Earth's tides are dominated by the combined effect of the Sun and the Moon's gravitational pull. But the other planets, since they have a gravitational pull of their own, also have a small effect on the tides. Venus is the strongest because it happens to come closest to Earth. However, even at its maximum, its influence is 10,000 times less than that of the Sun and Moon together. Even the giant planet Jupiter exerts a force less than one-tenth that of Venus. So, for all intents and purposes, the effect of the planets on Earth's tides is imperceptible. AGu

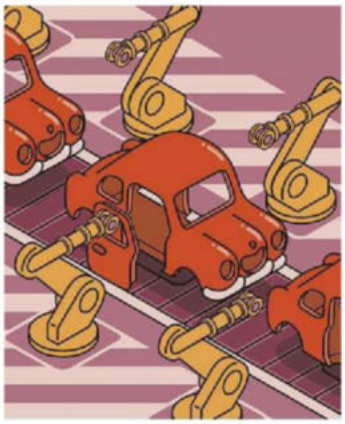
How do mussels stick to wet rocks?

CHRIS LIDDLE, POOLE

Hundreds of sticky threads, known as byssus, glue mussels to slippery, wave-pounded rocks. Mussels make the threads by squeezing quick-setting liquid protein into a groove in their muscly foot. The key ingredients are called 'mussel adhesive proteins', or MAPS, which form weak bonds with the rock. They're being investigated as the chemical inspiration for surgical glues that would work inside living bodies, and for the production of hard-wearing, self-healing polymers to manufacture replacement hip and knee joints. Synthetic MAPs may even be used to fix anti-fouling chemicals to the bottoms of boats, to stop animals like mussels from sticking on. **HS**

THE THOUGHT EXPERIMENT

WHAT IF EVERY PERSON ON EARTH HAD A CAR?



1. MANUFACTURE

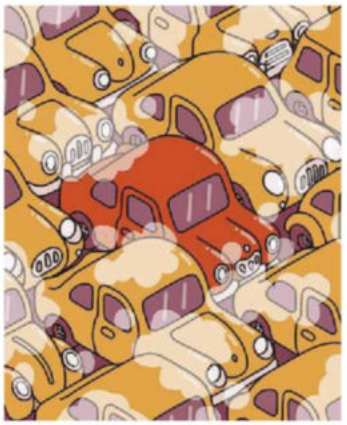
There are 1.2 billion cars in the world today, and 7.5 billion people. So we'll need at least 6.3 billion extra cars to make sure everyone has their own. This will require 5.6 billion tonnes of steel, which is 3.5 times as much steel as the world produces each year.

2. PARKING

On the roads, those 7.5 billion cars will occupy 36 million kilometres of road – about half the total length of all the roads in the world. Cars normally only spend about 5 per cent of their time on the road network, but there aren't 7.1 billion parking spaces either.

3. FUEL

Even with 95 per cent of them parked, the world's cars currently use 6.5 billion litres of petrol a day. If this demand scales linearly up to 7.5 billion cars, the oil industry will need to increase output more than five times, sending oil prices to hundreds of dollars per barrel.



4. EXHAUST

Cars today emit 2.5 billion tonnes of CO_2 into the atmosphere each year. If driving habits stay the same, increasing the world fleet to 7.5 billion cars will add another 13 billion tonnes per year. That's nearly half the current CO_2 produced globally by humans.

PHOTOS: GETTY X5, SCIENCE PHOTO LIBRARY. ILLUSTRATIONS: RAJA LOCKEY

Why is Big Ben being turned off for four years?

EVE TAYLOR, CLACTON

The Elizabeth Tower and the Great Clock are being completely renovated. Although the clock will only be out of action for two years, the bells have to be silenced for the entire renovation period to protect the workers' hearing. The Big Ben bell weighs 13.76 tonnes and chimes at 118 decibels. At that volume you will suffer hearing damage after just 14 seconds of exposure. To stop the bells, the weights that drive the mechanism have to be lowered to the bottom of the tower and secured. This takes half a day to do, so it isn't practical to restart them after each workday. But the chimes will be re-enabled for New Year's Eve and Remembrance Sunday. **LV**

IN NUMBERS

217

The number of mice spotted in the Palace of Westminster in the first half of 2017.

100m

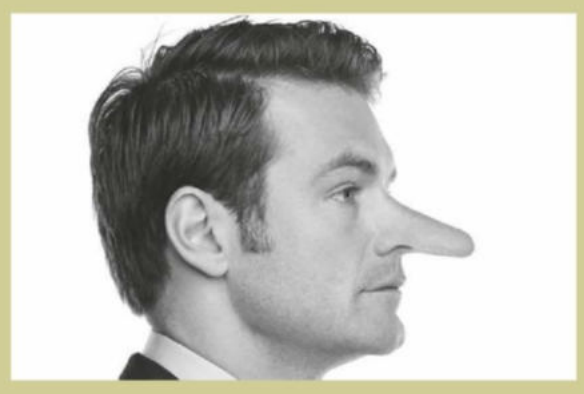
The number of black holes in the Milky Way, according to a new census.

2

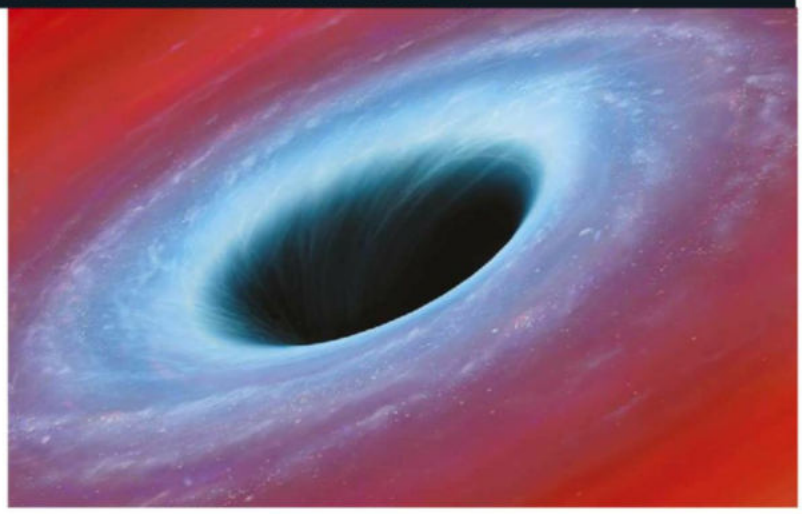
The age at which kids should start learning to code, according to computing pioneer Dame Stephanie Shirley.

Why do humans lie?

SULAYMAAN KHAN, LONDON



Most people lie occasionally, although there are individual differences in how often lies are told. Lying is a part of normal child development, emerging early in life. Research published in 2016 by Prof Timothy Levine, a communications expert, investigated reasons for lying. Most lies were told for selfish reasons, such as covering up a personal transgression or gaining an economic advantage. Lies were also told to protect the feelings of others and to maintain social politeness. Overall, it seems that lies occur when the truth poses an obstacle that someone wants to overcome. **AGr**



Do black holes collapse?

PATRICIA RODRIGUES, KING'S LYNN

The Schwarzschild radius (event horizon) of a black hole is sometimes thought of as the black hole's 'size'. It is proportional to mass, which means that more massive black holes have bigger Schwarzschild radii. Left alone, black holes lose mass due to 'Hawking radiation', so that their event horizons are slowly shrinking. A typical black hole would take many billions of times the age of the Universe to completely 'evaporate' and disappear. But, the interior of the black hole, or its 'singularity' (the point at which all the black hole's matter is concentrated) has already reached the limit of its density and cannot 'collapse' any further. **AGu**

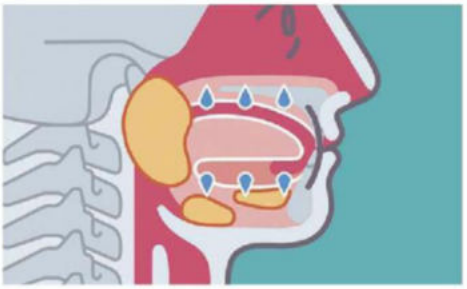
PHOTOS: GETTY X2, ALAMY, SCIENCE PHOTO LIBRARY ILLUSTRATIONS: RAJA LOCKEY

...WHEN I VOMIT?

Your body vomits when it senses various different threats. These threats can take the form of toxic chemicals or stress hormones in the blood, swaying motions, or an upset stomach. Chemicals and hormones are detected by the brain's chemoreceptor trigger zone (CTZ), swaying motions are detected by the inner ear, while an upset stomach is identified by the vagus nerve. Once the signal for a need to vomit arrives at the CTZ, it sets off a chain reaction.

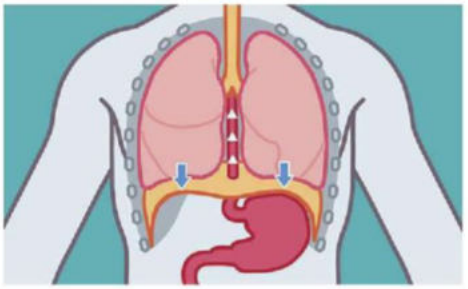
1. Brainstem

The chemoreceptor trigger zone (CTZ) receives a stimulus that might warrant vomiting. The vomiting centre begins a choreographed sequence of actions.



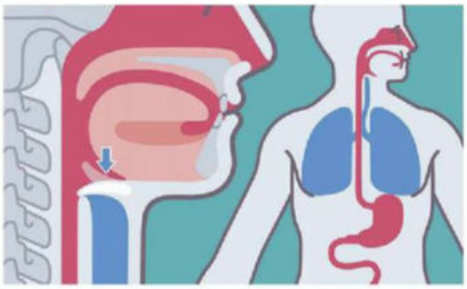
2. Salivary glands

Your mouth suddenly begins producing extra saliva. This is slightly alkaline and forms a buffer to protect your mouth and teeth from incoming stomach acid.



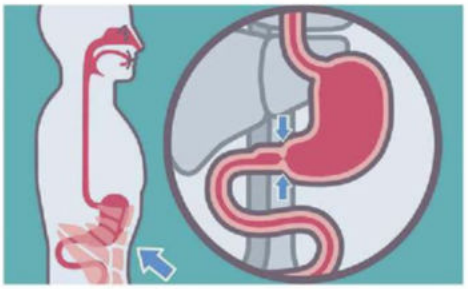
3. Diaphragm

You take a deep breath to avoid getting vomit in your lungs, then the diaphragm contracts in a few short pulses, squeezing the stomach to create pressure.



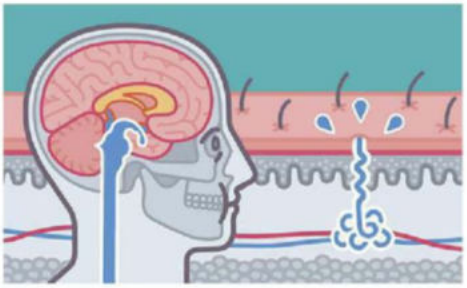
4. Glottis

The glottis closes, sealing the airway. Nothing enters or leaves the lungs. Diaphragm contractions without vomiting cause dry heaves.



5. Abdominal muscles

The abdominal muscles contract to further increase pressure. The pyloric sphincter at the bottom of the stomach is held closed. The only way out is upwards.



6. Skin

The sympathetic nervous system raises your heart rate and makes you sweat across your whole body, to shed the heat from this sudden exertion.

How do schools of fish swim in perfect unison?

LESLIE DAWES, PETERSFIELD

A fish decides where and how to move relative to its position in the school. If the fish behind gets too close (less than two body-lengths), then it speeds up; if the fish in front gets closer than that, then it slows down. Schooling fish watch one another and also feel the waves their neighbours make as they swim, with pressure-sensitive pores along their body called the lateral line. And each fish has its preferred spot in the school. Some are natural leaders and tend to hang at the front and guide the whole school, while others choose to follow. HS

How do scientists know 86 per cent of species remain to be discovered?

BRIAN LISLE, HUDDERSFIELD

This wide selection of wildlife can be found on California's coastlines

You can estimate the total number of species in the world by graphing the decreasing number of new species discovered each year to predict the end point. Or you can extrapolate the number of new species found per hectare of rainforest, to the number of hectares that haven't been studied. Or you can graph the body size of each new species found, on the assumption that larger species tend to be discovered sooner, and extrapolate that. The different statistical models over the years have been gradually homing in on a figure of 8.7 million total species. Currently, 1.64 million have been named, so that's 81 per cent left to find (the 86 per cent figure was based on 2011 totals). This only covers eukaryotes (animals, plants and fungi) though. A 2016 study estimated that bacteria could add almost another trillion species. **LV**

Why is yawning contagious?

LUKE WARD, LONDON

Yawning is contagious for both children and adults. Even certain animals, such as dogs, can catch a yawn! One study of adults showed that yawning becomes less contagious with age. Furthermore, children under the age of four and children with autism spectrum disorders may be less likely to yawn when they see others doing so. There are many theories as to why yawning is contagious. One possibility is that it helps synchronise people within a group, by signifying that it is bedtime, for example. Another suggests that it helps regulate our brain temperature. It may also be a sign of empathy – although not all studies support this idea. **AGr**

Why are water and electricity a deadly combination?

ASHLEY MARTIN, HAMPSHIRE

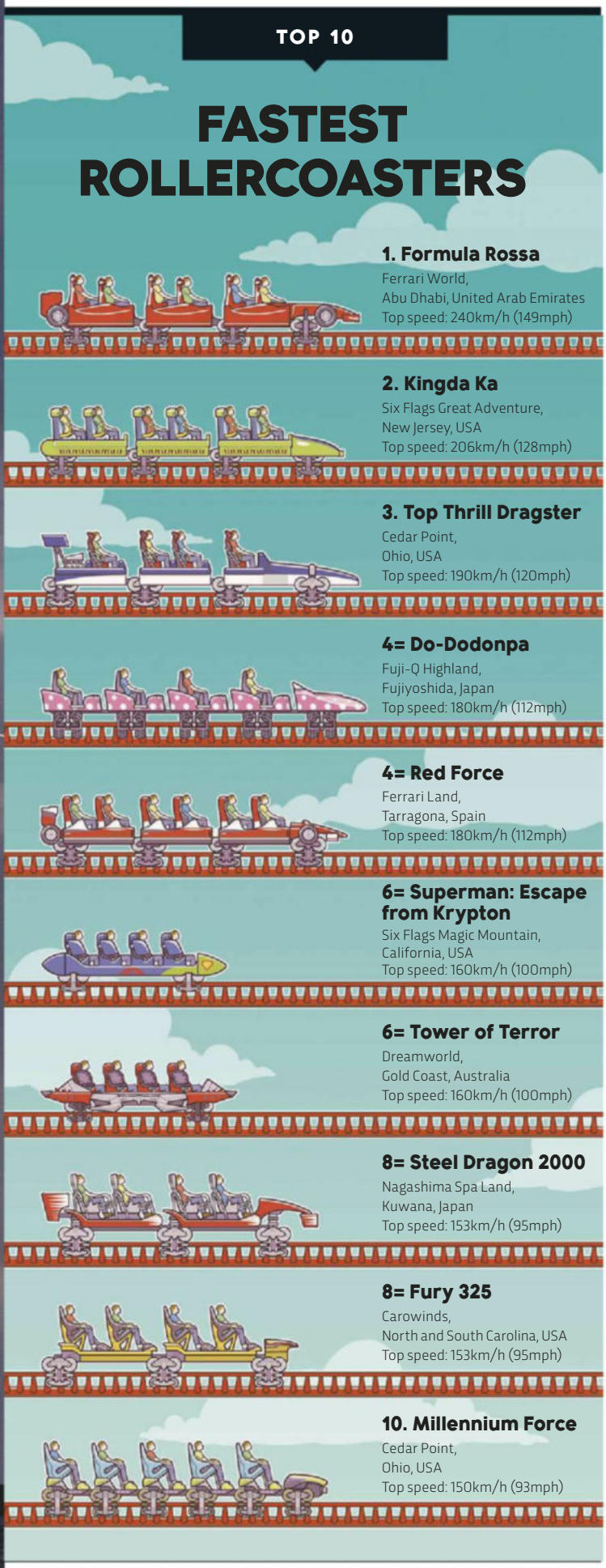
Water itself doesn't conduct electricity particularly well, it's the chemicals dissolved in it that are the source of the trouble. For example, the salt content of seawater makes it a million times better at conducting electricity than ultra-pure water. Even so, even a trace of water can prove fatal with high voltages. People have been killed thinking they can move live cables using a freshly broken tree branch. **RM**

PHOTOS: GETTY X3 ILLUSTRATIONS: RAJA LOCKEY

Love our Q&A pages? Follow our Twitter feed @sciencefocusQA

TOP 10

FASTEST ROLLERCOASTERS



1. Formula Rossa
Ferrari World,
Abu Dhabi, United Arab Emirates
Top speed: 240km/h (149mph)

2. Kingda Ka
Six Flags Great Adventure,
New Jersey, USA
Top speed: 206km/h (128mph)

3. Top Thrill Dragster
Cedar Point,
Ohio, USA
Top speed: 190km/h (120mph)

4= Do-Dodonpa
Fuji-Q Highland,
Fujiyoshida, Japan
Top speed: 180km/h (112mph)

4= Red Force
Ferrari Land,
Tarragona, Spain
Top speed: 180km/h (112mph)

6= Superman: Escape from Krypton
Six Flags Magic Mountain,
California, USA
Top speed: 160km/h (100mph)

6= Tower of Terror
Dreamworld,
Gold Coast, Australia
Top speed: 160km/h (100mph)

8= Steel Dragon 2000
Nagashima Spa Land,
Kuwana, Japan
Top speed: 153km/h (95mph)

8= Fury 325
Carowinds,
North and South Carolina, USA
Top speed: 153km/h (95mph)

10. Millennium Force
Cedar Point,
Ohio, USA
Top speed: 150km/h (93mph)

WHO REALLY INVENTED?

TELEVISION

JOHN LOGIE BAIRD

PHILO FARNSWORTH

Transmitting signals over long distances was one of the greatest triumphs of 19th-Century inventors. Yet even their ingenuity failed to solve the ultimate challenge: the transmission of clear sound and images. Many tried, leading to a long list of supposed 'pioneers' of television, the most famous being the Scottish inventor John Logie Baird. In January 1926 he gave the first-ever demonstration of the transmission of moving images, and by 1929 Baird was selling 'Televisor' sets for £25 – equivalent to £1,500 today. Baird's design offered small, flickering, black-and-white images and involved the use of a spinning, perforated disk invented in 1894 by German engineer Paul Nipkow that scanned images for transmission as electrical signals.

The technology needed to give television its mass appeal is generally credited to the brilliant American inventor Philo Farnsworth. While still a teenager, he realised that emerging electronic technology could scan images far faster and more finely than any mechanical device, and in 1927 demonstrated the first electronic television. A bitter patent dispute with the US electronics company RCA then broke out. Despite ultimately winning and being awarded a settlement plus royalties, Farnsworth and his key role in the invention of television are now largely forgotten. **RM**

Post-war German television

Can photosynthesis be recreated in the lab?

MATT FLINT, EDINBURGH

Photosynthesis is the process of using light energy to convert carbon dioxide into oxygen and carbohydrates. Plants and bacteria have been doing this happily for billions of years. In 1912, an Italian chemist called Giacomo Ciamician had the idea to copy nature. Eighty years later, the Swedish Consortium for Artificial Photosynthesis was established to work on the problem in earnest. Since then, artificial photosynthesis has been a major area of research all around the globe. The tricky things are making it efficient at the relatively low concentrations of carbon dioxide in the atmosphere and turning the lab-based science into a working technology! **ML**

Will electric cars reduce pollution?

KATE DENNIS, DURHAM

Electric vehicles' engines don't churn out polluting fumes, making them the obvious choice for improving local air quality in towns and cities. But although they have the potential to drastically cut pollution, they are only as green as the electricity they run on. Given that most electricity globally is still produced by burning fossil fuels, charging an electric car can indirectly generate similar amounts of greenhouse gases to a petrol-powered vehicle, particularly in countries that rely heavily on coal power. As the world embraces renewable energy, electric cars will increasingly gain the upper hand in years to come. **AFC**

PHOTOS: GETTY X3, ALAMY X2, ANDREI REINOL

WHAT IS THIS?

On ice

Sadly, this isn't an alien world. These weird formations are ice-covered wooden poles emerging from the sea at low tide. The poles are all that remains of a dock on the Paljassaare peninsula in Tallinn, Estonia. It must have been chilly on that day, because seawater requires temperatures of -2°C to freeze, which is a little colder than the 0°C required by freshwater.

WHAT'S IN...

...THE MMR VACCINE?

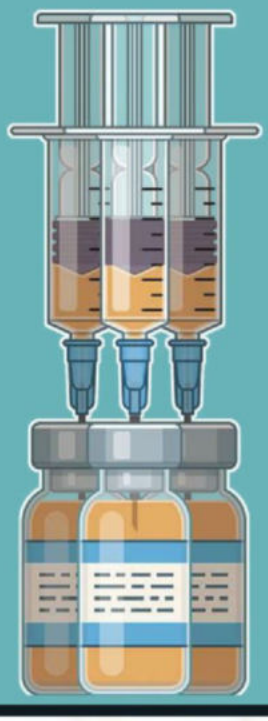
The active ingredient of vaccines can vary dramatically – they might take the form of live (but weakened) viruses, completely inactivated viruses or just fragments of a virus or bacteria. There are numerous ways the vaccine might be administered, for example, orally, nasally or by a jab. These factors require different components to make the vaccine easy to produce, effective and stable. Let's take a single dose of a measles, mumps and rubella jab as an example. **ML**

WATER
464.4mg
(93.47 per cent)

LIVE VIRUS PARTICLES
about 0.003mg
(0.0006 per cent)
The smallest component of the vaccine are the weakened measles, mumps and rubella viruses.

HYDROLYSED GELATIN
15mg (3 per cent)
A stabiliser that protects the viruses from the effects of changing temperatures during preparation and storage.

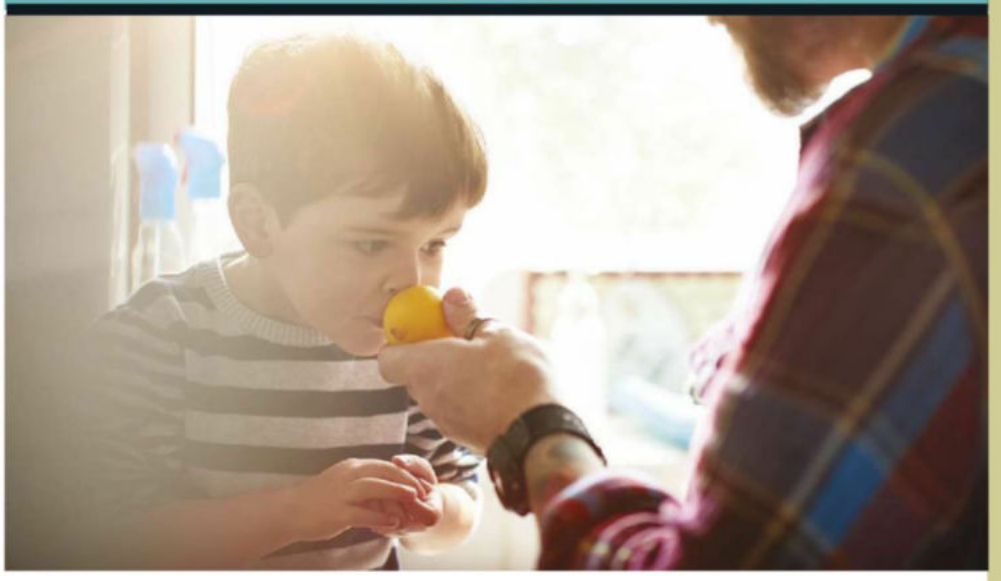
SODIUM PHOSPHATE
0.3mg (0.06 per cent)
This keeps the whole thing at a pH that the viruses need to stay alive.



RECOMBINANT HUMAN ALBUMIN
about 0.3mg
(0.06 per cent)
Another stabiliser made by bacteria engineered to produce a human protein.

SORBITOL
15mg
(3 per cent)
This is more commonly used as an artificial sweetener. Here, it acts as another stabiliser.

SUCROSE
2mg (0.4 per cent)
Yet another stabiliser!



Do children have a better sense of smell than adults?

TIM HARRISON, SUTTON

Newborns can only smell a few different things, such as their mother's body smell. Sense of smell improves up to about the age of eight. But from the age of 20 (or even 15, according to some studies), the sense gently declines. Yet some studies have found that children can't detect certain musk odours until they reach puberty. **LV**

WHAT CONNECTS...

...KOALAS AND TABLE MANNERS?

1.
Koalas
Koalas mostly eat eucalyptus leaves. These have a high water content, so koalas hardly need to drink. This lets them stay in the trees, safe from predators.

2.
Energy
But eucalyptus is a low energy food. Even though koalas eat over 1kg of leaves per day, they must spend 18-20 hours a day sleeping, to conserve energy.

3.
Brain power
Their low-energy lifestyle means koalas can't sustain a large brain. At just 0.2 per cent of body weight, koala brains are one of the smallest of any mammal.

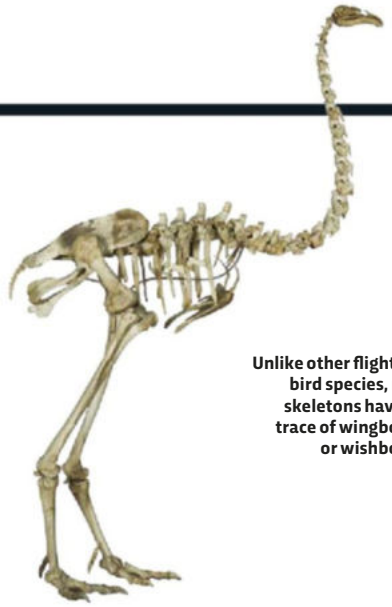
4.
Table manners
Their tiny brains can't deal with unfamiliar situations. If you give koalas eucalyptus leaves on a flat surface, like a plate, they won't recognise them as food and won't eat them.

PHOTOS: GETTY X4, ALAMY X3 ILLUSTRATIONS: RAJA LOCKEY

Could Jupiter become a star?

LOUISE DRYDEN, CARDIFF

Jupiter is often called a 'failed star' because, although it is mostly hydrogen like most normal stars, it is not massive enough to commence thermonuclear reactions in its core and thus become a 'real star'. But the term 'failed star' is a bit of a misnomer. Theoretically, any object at all could be made into a star, simply by adding enough matter to it. With enough mass, the internal pressure and temperature of the object will reach the threshold needed to start thermonuclear reactions. That threshold is the least for the simplest element, hydrogen. In order to turn Jupiter into a star like the Sun, for example, you would have to add about 1,000 times the mass of Jupiter. But, to make a cooler 'red dwarf' you would only need to add about 80 Jupiter masses. Although the exact numbers are still a bit uncertain, it is possible that a 'brown dwarf' could still form (in which deuterium, rather than hydrogen, fuses in the star's core) with only about 13 Jupiter masses. So, Jupiter cannot and will not spontaneously become a star, but if a minimum of 13 extra Jupiter-mass objects happen to collide with it, there is a chance it will. AGu



Unlike other flightless bird species, moa skeletons have no trace of wingbones or wishbones

How long does DNA last?

RACHEL HARRISON, CANTERBURY

A study of DNA extracted from the leg bones of extinct moa birds in New Zealand found that the half-life of DNA is 521 years. So every 1,000 years, 75 per cent of the genetic information is lost. After 6.8 million years, every single base pair is gone. Bacterial RNA is much tougher and sequences have been recovered from ice crystals that are 419 million years old. These are only short fragments of 55 base pairs though. **LV**

QUESTION OF THE MONTH

Why are most people right-handed?

ALFIE O'CONNOR, SOUTHAMPTON

Many animals show a preference for one side of the body over another but the split between right- and left-handed varies. Seven out of ten chimpanzees are right-handed, but almost all kangaroos are left-handed. In cats, males are nearly all left-handed and females are nearly all right-handed. Humans have a higher proportion of right-handers than any species, with left-handers making up just 10 per cent of the population. This is because we are a tool-using species, and also highly social. The very earliest flint tools, around two million years ago, don't show a strong bias towards left- or right-handed versions. But it's a big advantage if you can use the tools someone else has made, and from about 1.5 million years ago we seem to have standardised on the right-handed versions. It's not exactly clear why right-handedness won, but it may be that one side of our brain was already specialised for fine-motor control. One theory why left-handedness hasn't been completely eliminated is that it provides an advantage in combat, precisely because it is rarer, and therefore unexpected. You can see this today in sports like tennis, where left-handed professionals are more common than in the general population. **LV**

WINNER!

Alfie O'Connor wins a Fitbit Flex 2 (£69.99, **fitbit.co.uk**). This stylish fitness tracker will measure steps, activities, sleep, and calories burnt. It will also offer call and message alerts, and is swim-proof too!

NEXT ISSUE:

Are we running out of sand?

Why do gums recede?

Why do people like horror films?

Email your questions to **questions@sciencefocus.com** or submit online at **sciencefocus.com/qanda**

GALAXY ON GLASS

Spectacular wall art from astro photographer Chris Baker. A range of images are available as frameless acrylic-aluminium mix or framed backlit up to 1.2 metres wide. A big impact in any room. All limited editions.

www.cosmologychris.co.uk
www.facebook.com/galaxyonglass

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

OCTOBER 2017 | EDITED BY JAMES LLOYD

01

WILDLIFE PHOTOGRAPHER OF THE YEAR 2017
NATURAL HISTORY MUSEUM, LONDON,
20 OCTOBER 2017–SPRING 2018 .

GO WILD FOR PHOTOGRAPHY

A tiny estuary seahorse grips a cotton bud like a makeshift staff in this shortlisted image from the Wildlife Photographer of the Year 2017 awards. Snapped by Justin Hofman near the Indonesian island of Sumbawa, the photo provides a stark reminder of the plastic in our oceans, which is predicted to outweigh the fish by 2050. In last year's Great British Beach Clean, cotton buds were one of the most frequently found items.

The photo will go on display alongside the other finalists in an exhibition at London's Natural History Museum, opening 20 October.

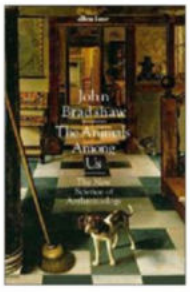
PHOTO: JUSTIN HOFMAN/WILDLIFE PHOTOGRAPHER OF THE YEAR

02

CELEBRATE OUR PETS

With around half of UK households owning a pet, it seems we can't get enough of our animal companions. But why do we keep pets at all? JOHN BRADSHAW argues that the answer can be found deep in our evolutionary past

THE ANIMALS AMONG US
BY JOHN BRADSHAW
OUT 28 SEPTEMBER (£20, ALLEN LANE).



Pets can be costly, time-consuming, and often quite smelly. Why do so many of us keep them?
It's a question we rarely ask. No other animal keeps pets, but it's pretty much universal among humans. So what is this strange thing we do? Is it just a hangover from our agricultural past, when we needed domesticated animals for things like transport, hunting and herding, or is it something that runs deeper? I think it's the latter: keeping pets is an intrinsic part of human nature, and something that we're hardwired to do.

How long have humans kept pets?
The evidence suggests it goes back tens of thousands of years, before the dawn of agriculture. The archaeological record doesn't tell us anything about the first pets, because these would have been wild animals brought into a domestic setting, with fossilised remains identical to animals that still lived in their original habitats. So the best evidence comes from hunter-gatherer societies who survived into the 19th and 20th Centuries, in places like Amazonia, Siberia and New Guinea.

Anthropologists have observed these tribes capturing young animals in the wild and then hand-raising them in the village, treating them almost like members of the family. It's highly unlikely that these societies all simultaneously picked up this pet-keeping behaviour from westerners, who they'd barely met and were suspicious of, so we think it's an ancient habit.

There are lots of reasons people give for keeping pets today: exercise, companionship, a fondness for furry creatures. Does our urge to keep pets go beyond this?
I think it goes back to around 50,000 years ago, when we first started to anthropomorphise animals and imagine what it might be like to *be* them, and hence predict what they might do next. Evidence comes from the development of new hunting methods around this time, and art artefacts showing animal and human features fused together. This ability to 'think' like animals would have made us better hunters, but paradoxically might also have led to us developing affection for them.

Evolutionarily speaking, there are two reasons why keeping pets might have benefited our ancestors. First, being good with animals could have acted as a kind of 'personality proxy' for those looking for a marriage partner, showing that this person would

PHOTO: GETTY

Humans all over the world have kept pets since time immemorial

make a good, gentle parent. Second, pet-keeping might have provided a psychological barrier between the domestic animal and its wilder cousins. If a neighbouring tribe decided it liked the look of your pigs, it might be less likely to eat them if the pigs were classed as your friend, rather than just your food. We still have this barrier today, of course, when it comes to the animals we choose to eat.

How did these first 'pets' eventually become domesticated?
The domestication of animals began with the dog, between 30,000 and 15,000 years ago. Once our ancestors had isolated a population of an animal [preventing the animals from interbreeding with their wild relations], they could start to domesticate it. Thousands of years ago, this would have been a kind of natural selection, with those animals able to cope in close proximity to humans surviving and propagating their genes. In our more recent history, deliberate breeding took over.

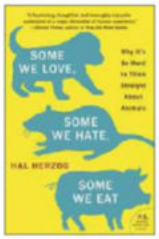
Today, we're beginning to see robotic companions – do you think these will ever replace live animals as pets?
Robotic pets have been very successful in some contexts, particularly with the elderly, so I expect we'll see more of them – especially as they become more lifelike. Our pets consume a lot of resources, so we might see people being put under pressure to consider the robotic alternatives. But I think that would be a shame. Pet owners have been shown to have a stronger connection with wild animals, and in turn the health of our planet. We need our pets – in all their messy, unpredictable reality.

AUTHOR'S BOOKSHELF

Three books that inspired John Bradshaw while writing *The Animals Among Us*

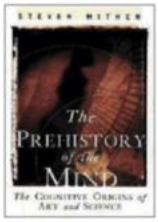
IN THE COMPANY OF ANIMALS
BY JAMES SERPELL
(£24.99, CAMBRIDGE UNIVERSITY PRESS)

The work that defined anthrozoology before the discipline even had a name. It was the first account to attempt a balanced and dispassionate view of pet-keeping, and to emphasise its historical context. A classic.



SOME WE LOVE, SOME WE HATE, SOME WE EAT
BY HAL HERZOG
(£10.99, HARPERCOLLINS)

Highly entertaining while at the same time deeply thought-provoking, this book tackles the contradictions implicit in our modern relationships with animals – animals in our homes, on supermarket shelves, in laboratories, in blood sports.



THE PREHISTORY OF THE MIND
BY STEVEN MITHEN
(£14.99, WEIDENFELD & NICOLSON)

When did humankind first evolve the ability to imagine the thoughts of animals, and why? Mithen's lecture at the 1998 conference of the International Society for Anthrozoology made me realise that there might be an evolutionary explanation for why we keep pets.

03

MANCHESTER SCIENCE FESTIVAL
VARIOUS VENUES, 19–29 OCTOBER
MANCHESTERSCIENCEFESTIVAL.COM

TOUR MANCHESTER

The Science Museum's acclaimed *Robots* exhibition comes to Manchester in October

The *BBC Focus* team will be heading north this October half-term for Manchester's annual science festival. Billed as "part laboratory, part playground," the festival is produced by the city's Museum of Science and Industry, which will open its blockbuster *Robots* exhibition (previously seen at London's Science Museum) on 19 October. Also at the museum, the 1830 Warehouse will be transformed into a giant, climbable spider's web made from sticky tape, inspired by the real-life engineering skills of our eight-legged friends.

Other events across Greater Manchester include the *Library of Fake News* at the University of Salford, where visitors will learn how to take the spin out of news stories, and *CSI Manchester* at Minshull Street Crown Court, which will play host to a mock trial, inviting visitors to have a go at interpreting the forensic evidence for themselves. For those with a strong stomach, Gallery Oldham will offer practical demonstrations of taxidermy, while sci-fi lovers will be satiated with an *X-Files*-themed party and a 30th anniversary screening of *RoboCop*. See you there!

DON'T MISS

NORWICH SCIENCE FESTIVAL
21–29 OCTOBER
NORWICHSCIENCEFESTIVAL.CO.UK

This year's Norwich Science Festival features appearances from Prof Alice Roberts, Robin Ince and Britain's first astronaut, Helen Sharman.

04

WHY MUSIC? THE KEY TO MEMORY
13–15 OCTOBER, WELLCOME COLLECTION / BBC RADIO 3
WELLCOMECOLLECTION.ORG/WHYMUSIC

TUNE IN TO RADIO 3

Music and memory are intimately entwined. A blast of a song on the radio can whisk us into the past, earworms can burrow deep into our mind, and it's been shown that our musical tastes are dictated by the 'reminiscence bump' – the time in our late adolescence and early adulthood when we form our strongest memories.

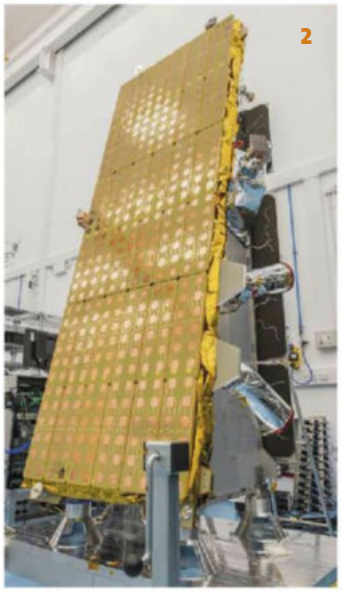
Broadcasting live on BBC Radio 3, a free weekend of talks, performances and activities at the Wellcome Collection will explore these links. Highlights include neuropsychologist Dr Catherine Loveday discussing the reminiscence bump, an *Early Music Show* special looking at how music helped monks remember prayers, and a six-hour 'slow radio' sequence which uses music to bind together the voices of people living with dementia.

05

ILLUMINATING INDIA
SCIENCE MUSEUM, LONDON
4 OCTOBER 2017–31 MARCH 2018
SCIENCEMUSEUM.ORG.UK/INDIASEASON

DISCOVER INDIAN SCIENCE & TECH

Illuminating India is a new exhibition at the Science Museum that looks at the Indian subcontinent's contributions to science and culture globally. We asked curator, MATT KIMBERLEY, to pick his five favourite objects from the exhibition



1. INDUS VALLEY CIVILISATION WEIGHTS

The Indus Valley Civilisation arose around the same time as Ancient Egypt and Mesopotamia. Archaeologists have found large numbers of weights where Indus Valley cities once stood. It is likely they were used to measure everything from food to gemstones, and they show that the people of the Indus Valley had the mathematical tools and knowledge to build great cities and design complex systems for channelling and storing water. *From Science Museum Group collection.*

2. NOVASAR SATELLITE MODEL

The NovaSAR satellite, due to launch in late 2017, can capture high-res images through heavy cloud and even in total darkness. It will be used for monitoring major disasters and detecting oil spills worldwide. It was built by Surrey Satellite Technology and is being launched by the Indian Space Research Organisation on one of their Polar Satellite Launch Vehicles – an example of the important collaborations going on between the UK and India in science and technology. *From Surrey Satellite Technology Ltd.*

3. JAMBŪDVĪPA, OR JAIN MAP OF THE WORLD

According to ancient Jain beliefs, at the centre of the Universe is the continent of Jambūdvīpa, shown on this map. Because of the vast size of Jambūdvīpa, the Jains invented new ways of working with very large numbers. They categorised numbers as enumerable (countable), innumerable (countless) and infinite (unlimited). The Jains used the idea of Jambūdvīpa to explain how to calculate these numbers, including different types of infinity. *From the Royal Asiatic Society.*

4. REPLICA AYURVEDIC SURGICAL TOOLS

The Suśrutasamhita is one of the world's earliest medical texts. Written in around 500 BC, it describes a range of tools and techniques, from how to control bleeding to the surgical reconstruction of the nose.

Many of the designs of surgical instruments in the Suśrutasamhita were inspired by the teeth, jaws, claws and beaks of different animals. The instrument pictured, which has been reconstructed from a description in the original text, is based on a wolf. *From the Wellcome Collection.*

5. OSCILLATING PLATE PHYTOGRAPH

Jagadish Chandra Bose is often referred to as the father of modern Indian science. His work was wide ranging, but in the early 1900s Bose became fascinated by how plants respond to stimuli and invented several instruments to study this.

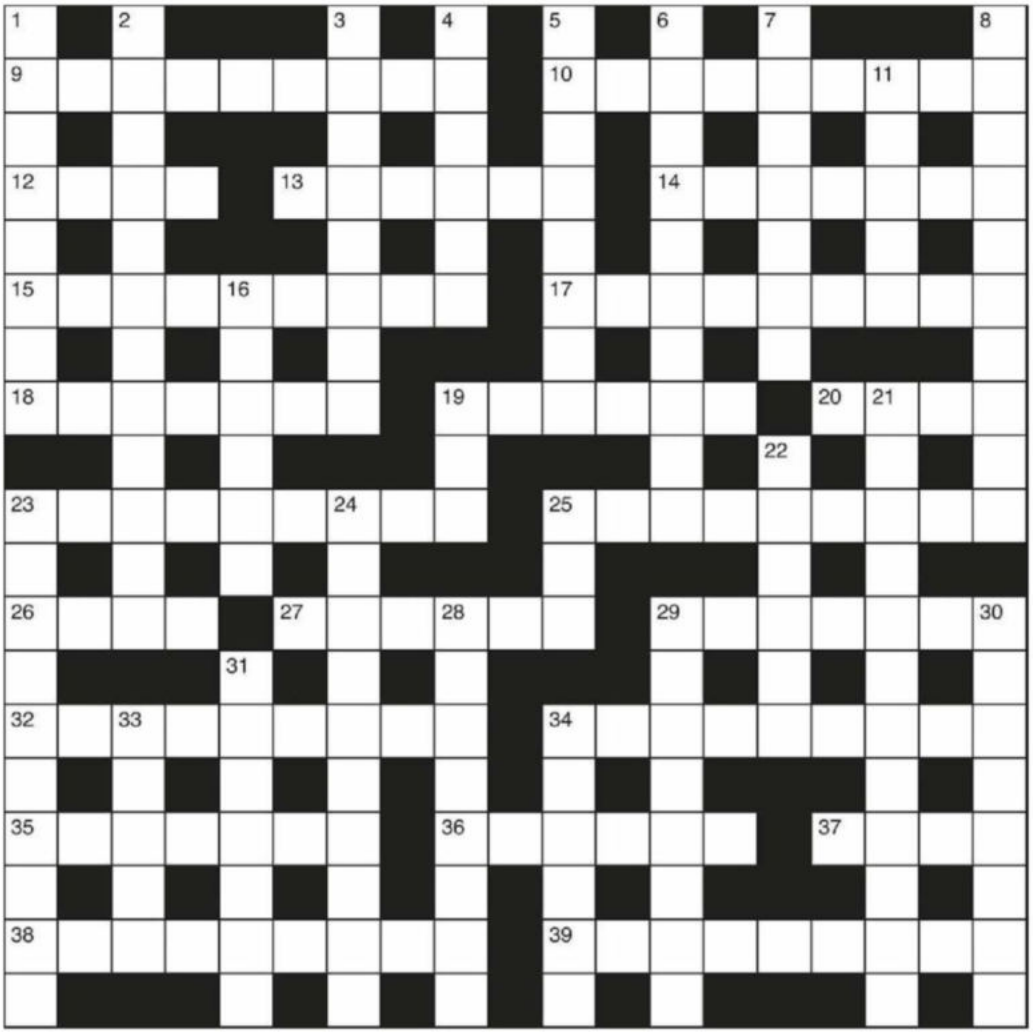
The phytograph measured how conditions like light, temperature and gravity changed the speed and direction of plant growth. These investigations into the responsiveness of organic matter, together with his earlier studies of inorganic matter, led to the new field of biophysics. This shed light on the unity of the natural world *From the JC Bose Science Heritage Museum collection.*

FIND OUT MORE

For more of this month's best events, shows and books, head to bit.ly/BBCFocusBrainFood

PHOTOS: GETTY, AIRBUS, SCIENCE MUSEUM GROUP X3

BBC FOCUS CROSSWORD
GIVE YOUR BRAIN A WORKOUT



DOWN

1 Moon about and complain – it only flowered once (8)
2 Hermit's polio turned out to be a response to sunlight (12)
3 Tom's gran travelled a very short distance (8)
4 A new decoration for county (6)
5 Graceful to cite adjustment after party (8)
6 I undid omen about musical direction (10)
7 German prisoner returns Greek character some dumplings (7)
8 Canes used to get routine domination (10)
11 Hour wasted by northern lake (5)
16 Wild curs get very loud on one's neck (6)
19 Regard for diocese (3)
21 Mortician put away an element (12)
22 A maths problem gets a complaint (6)
23 Omit chisel used in part of Stone Age (10)
24 If I can work with oxygen, bother connoisseur (10)
25 Doctor and wife make reduction in the garden (3)
28 Feeling ten-ten is wrong (8)
29 Glasses and key calf is wearing get old (8)
30 Neither seem upset by new Vikings (8)
31 Tolerant person receiving treatment (7)
33 Stop you in France acquiring other languages (5)
34 Continue the summary (6)

ACROSS

9 Oracle upset by French veto, getting the elbow (9)
10 Type of asbestos is a main problem like this (9)
12 Poet of providence (4)
13 Last performance with artist of the stars (6)
14 Turn inwards at home, remedy gaining victory (7)
15 Ruminates about disease treatment (9)
17 Difficult need to order type of glass (9)
18 Some rock takes memory in some software (7)
19 Attendant has little time (6)
20 Parking offence outside gets biased interpretation (4)
23 Chap gets one to surround large computer (9)
25 Design most on single semi-precious item (9)
26 Dine with Frenchman at reservoir (4)
27 Dance, having spotted a puzzle (6)
29 Expression of disgust at bad conditions to land (7)
32 Sign managed to take in one bookkeeper (9)
34 Judge right to get thespian a telescope (9)
35 One isn't affected by anxiety (7)
36 Creature found within group (6)
37 The queen in the banner (4)
38 Professor follows island bird waste to find dinosaur (9)
39 Large number of musicians' group sees bird in duel, struggling (9)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

Dr Eleanor Schofield

"I like the artefacts that you look at and realise how little the technology has changed"

It's now 35 years since the *Mary Rose* was raised from the bottom of the Solent. This month, **Helen Pilcher** talks to **Eleanor Schofield**, head of conservation and collections care at the Mary Rose Trust

The *Mary Rose* sank on her maiden voyage, right?
No, she didn't. It's a common misperception that we just can't seem to put to rest. The *Mary Rose* was a successful warship, in service for 34 years, for almost the entire duration of Henry VIII's reign. We have a big sign explaining this in the museum, but you still hear people wandering around saying, "I can't believe she sank on her first voyage."

What does your job involve?
I'm in charge of the conservation and maintenance of the *Mary Rose*, and the management of all the artefacts recovered with her.

What science is involved?
There's lots of science. As the ship lay under the seabed for hundreds of years, lots of chemicals, such as iron and sulphur, became incorporated into the wood. Some of these have the potential to form acids, which are corrosive. We used X-rays from a synchrotron to work out what these iron- and sulphur-based compounds are.

How do you stop the *Mary Rose* from deteriorating?
We've put a lot of research into that. The hull was sprayed continually for three decades; first with water to keep it wet and stop it drying out, then with polyethylene glycol which infiltrates the wood and supports it when it dries. Working conditions were really tough during this phase. The humidity was 98 per cent. It was dirty, wet and slippery. When we went in to take measurements we had to wear protective suits and oxygen helmets. I now have researchers working to devise new treatment strategies.

Why is the *Mary Rose* so special?
It's a time capsule of Tudor maritime life. We can learn so much about the lives of the people who were on board. The ship is now on display at Portsmouth Historic Dockyard alongside many of the thousands of artefacts recovered from it.

Tell me something surprising about the *Mary Rose*...
Isotope analysis of human remains suggests that some of the ship's crew came from southern Europe, so they could have been hired mercenaries, paid to fight for the king. There are lots of theories about why the *Mary Rose* sank. Some people think it is because gun ports hadn't been closed and the ship turned too quickly, but it could be that this hired crew were unruly or difficult to control. We just don't know.

What's your favourite artefact?
I like the ones that you look at and realise how little the technology has changed. There are wooden combs that look identical to the two-sided nit combs used today.

What do you do at the end of the day when you go home?
I love my job but it can be all-consuming, so it's nice to get some downtime. I live by the beach, so when it's warm, I'll go there to walk or jog or read. I also like getting stuck into something on Netflix.

If you weren't a scientist, what would you be?
I'd be a dancer on *Strictly*. I think they're so fabulous. It must take so much determination and practice to become that physically fit. I really admire that.

Dr Eleanor Schofield is in charge of the conservation of the *Mary Rose*. Find out more at maryrose.org

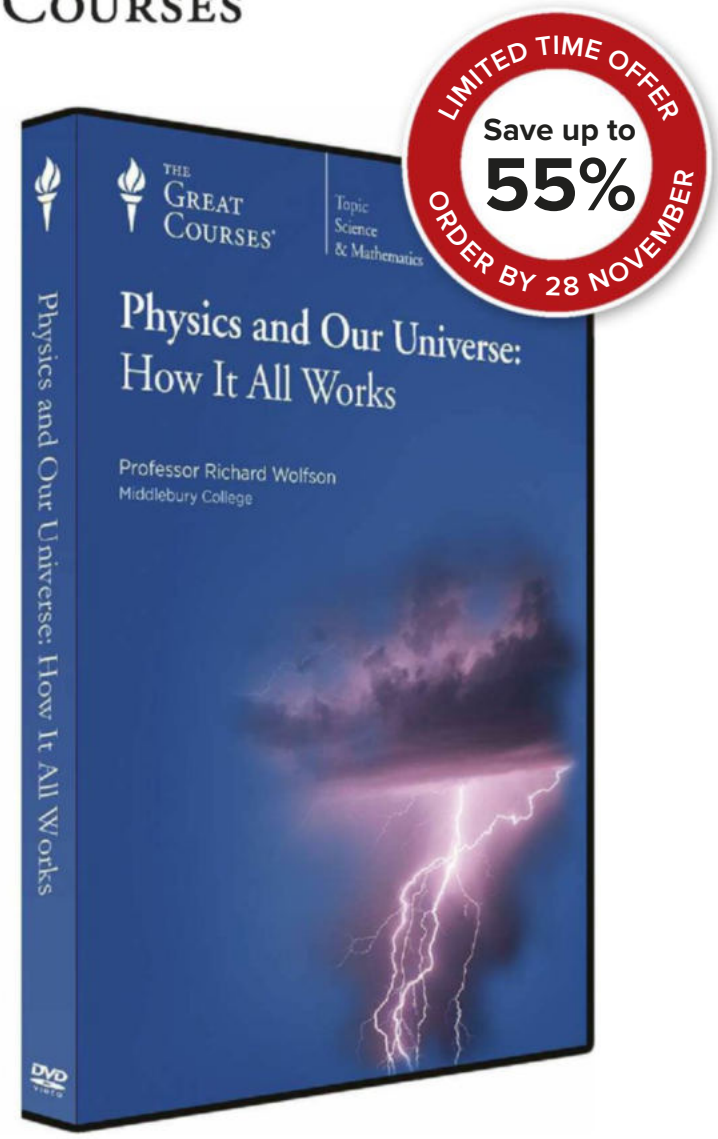
DISCOVER MORE

BBC Radio 4 To listen to episodes of *The Life Scientific* with top scientists visit **bit.ly/life_scientific**

NEXT ISSUE: ANDREW DIGBY

ILLUSTRATION: DAVID DESPAU

THE GREAT COURSES®



Physics—Made Clear

Physics is *the* fundamental science. It explains how the universe behaves and gives us an extraordinary power over our world. This makes physics sound like the most complicated subject there is, but it isn't. In fact, physics is so simple that anyone with a willingness to learn can grasp its unlimited wonders.

In 60 enthralling lectures, **Physics and Our Universe: How It All Works** proves that case, giving you a robust introduction to physics using nothing more advanced than secondary school algebra. Noted physicist and Professor Richard Wolfson's lectures—intensively illustrated with diagrams, animations, graphs, and other engaging visual aids—introduce you to scores of fundamental ideas related to Newtonian mechanics, oscillations and waves, thermodynamics, electricity and magnetism, optics, quantum theory, and more.

Offer expires 28/11/17

THEGREATCOURSES.CO.UK/7FS

0800 298 9796

Physics and Our Universe: How It All Works

Taught by Professor Richard Wolfson
MIDDLEBURY COLLEGE

LECTURE TITLES

1. The Fundamental Science
2. Languages of Physics
3. Describing Motion
4. Falling Freely
5. It's a 3-D World!
6. Going in Circles
7. Causes of Motion
8. Using Newton's Laws—1-D Motion
9. Action and Reaction
10. Newton's Laws in 2 and 3 Dimensions
11. Work and Energy
12. Using Energy Conservation
13. Gravity
14. Systems of Particles
15. Rotational Motion
16. Keeping Still
17. Back and Forth—Oscillatory Motion
18. Making Waves
19. Fluid Statics—The Tip of the Iceberg
20. Fluid Dynamics
21. Heat and Temperature
22. Heat Transfer
23. Matter and Heat
24. The Ideal Gas
25. Heat and Work
26. Entropy—The Second Law of Thermodynamics
27. Consequences of the Second Law
28. A Charged World
29. The Electric Field
30. Electric Potential
31. Electric Energy
32. Electric Current
33. Electric Circuits
34. Magnetism
35. The Origin of Magnetism
36. Electromagnetic Induction
37. Applications of Electromagnetic Induction
38. Magnetic Energy
39. AC/DC
40. Electromagnetic Waves
41. Reflection and Refraction
42. Imaging
43. Wave Optics
44. Cracks in the Classical Picture
45. Earth, Ether, Light
46. Special Relativity
47. Time and Space
48. Space-Time and Mass-Energy
49. General Relativity
50. Introducing the Quantum
51. Atomic Quandaries
52. Wave or Particle?
53. Quantum Mechanics
54. Atoms
55. Molecules and Solids
56. The Atomic Nucleus
57. Energy from the Nucleus
58. The Particle Zoo
59. An Evolving Universe
60. Humble Physics—What We Don't Know

Physics and Our Universe: How It All Works
Course no. 1280 | 60 lectures (30 minutes/lecture)

SAVE UP TO £60

DVD	~~£114.99~~	NOW £54.99
Video Download	~~£84.99~~	NOW £54.99

+£2.99 Postage and Packing (DVD only)

Priority Code: 151487

For over 25 years, The Great Courses has brought the world's foremost educators to millions who want to go deeper into the subjects that matter most. No exams. No homework. Just a world of knowledge available any time, anywhere. Download or stream to your laptop or PC, or use our free apps for iPad, iPhone, Android, or Kindle Fire. Over 600 courses available at www.TheGreatCourses.co.uk.

SAVE MONEY ON YOUR BROADBAND AND TV BILLS WITH THE CARPHONE WAREHOUSE SWITCHING SERVICE

SAVE UP TO £322* A YEAR

Call: 0800 090 1669

Save money and still get the service you want, with a little help from us

SWITCH IN THREE SIMPLE STEPS

1. call our freephone number:
   0800 090 1669
   Our lines are open:
   Monday - Sunday, 8am-9pm
2. Tell us how you use the internet and TV at home
3. We'll help you switch to the perfect deal so you can just sit back and relax

How much are you spending every month on your internet and TV service? If you've been with the same provider for 12 months or more, it's likely you could save up to £322* a year by switching to a service which is tailored to your needs.

Pick up the phone and speak to one of our friendly UK advisors. They'll listen to your requirements and then recommend the right service for you, using our Ofcom-approved calculator to compare over 11,000 deals on your behalf.

If you are happy with the package we find you, we can organise everything in a few minutes while you're on the phone with us. Most people have their new service installed within 3 weeks of calling. It really is that simple.

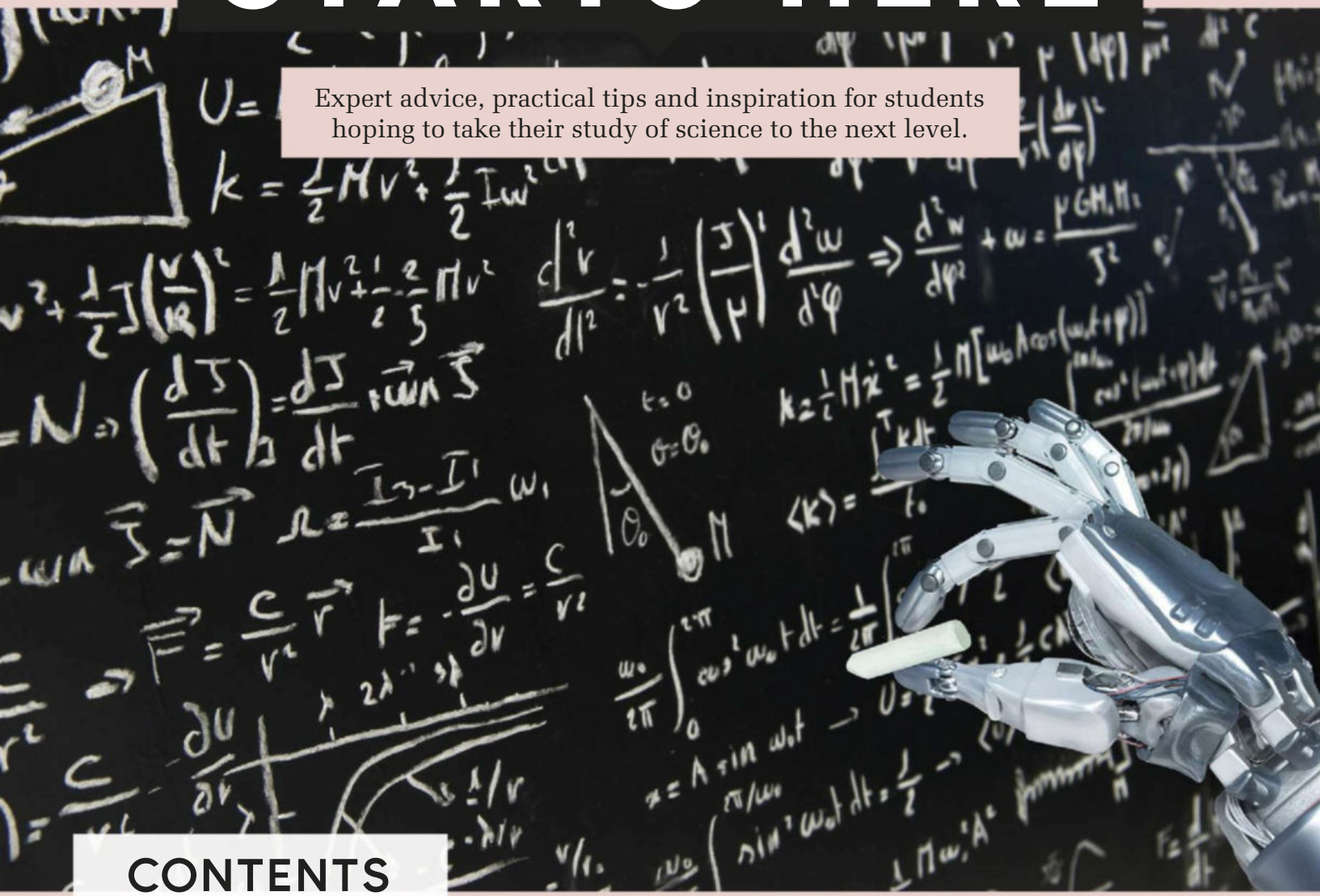
We compare the major UK internet, TV and Phone suppliers, including:

TalkTalk For Everyone · Virgin media · sky

*SimplifyDigital customers save on average £322 a year. Data based on 4,342 SimplifyDigital records between July – September 2016.

BBC FOCUS
EDUCATION GUIDE

YOUR FUTURE STARTS HERE



Expert advice, practical tips and inspiration for students hoping to take their study of science to the next level.

CONTENTS

"

So you're passionate about science and are considering taking a STEM course at university but are a little overwhelmed by the options. Fear not, we've got your back.

Over the following pages we'll take you through the application process, give you an insider's view of what to expect from a STEM course, and give you some examples of the varied and exciting places a STEM degree can take you.

We hope you find this is a useful guide to help you plan your future in science."

University of Dundee

Study science and engineering at the Scottish University of the Year 2017

science & engineering

The University of Dundee's School of Science and Engineering offers degrees in:

Anatomical Sciences
Forensic Anthropology
Computing
Biomedical, Civil, Electronic and Mechanical Engineering
Mathematics
Physics

Contact us:
E: contactus@dundee.ac.uk
T: 01382 383838
@dundeeuni
uod.ac.uk/science

HOW TO WRITE THE PERFECT UNIVERSITY APPLICATION

You've decided that a degree in one of the sciences is for you. The next step is applying to university. Dr Ben Maughan, of The University of Bristol's School of Physics, explains how to do it successfully.

A successful application begins long before you start filling in your UCAS form. It begins by figuring out what subject you want to study and where you can go to study it.

When it comes to science, the subjects you'll be able to study at university will be determined by what A-levels you've taken – most physics courses, for example, will require an A-level in maths as well as physics. So the first step in the application process really needs to be taken before you choose your A-levels.

The sooner you can get a clear idea of the direction you'd like your studies to follow the better. Then you can check the A-level (or equivalent) subject requirements of the degree courses you're interested in and use those to inform your choices. (Don't worry if you don't have the right A-level background, however, there are still routes into studying a science degree and we'll get to those later.)

Of course, once you've chosen the relevant A-levels, you then need to get the necessary grades in those subjects.

Your grades

Don't be put off applying to universities with typical A-level offers that are higher than your predicted grades. Some universities, including The University of Bristol, may make their normal offers to students with predictions that are several grades below those specified for the courses. This is because predicted grades may not be reliable and we want to give students the opportunity to exceed the predictions that have been made for them. Also, depending on the space available on the course after the A-level results are published, students who achieved grades just below their offer but who would be expected to succeed on the course may be accepted. It's worth noting that different courses place different emphases on A-level results. At The University of Bristol, some courses, such as chemistry, select students based entirely on their A-level results, while others – biochemistry and neuroscience, for example – will factor in GCSE results too.

The precise formulation of admissions requirements varies between universities though so don't assume that the grades that'll get you into one university will get you into another. Contact the universities you're interested in or check their websites to find out exactly what they look for in successful applicants. The University of Bristol publishes admissions statements for every degree course (www.bristol.ac.uk/study/undergraduate/apply/admissions-statements). These will tell you how much weighting is put on your GCSEs, A-levels (or equivalent qualifications) and personal statements.

Your background

If you don't have the right A-level background, then Access to Higher Education courses (www.accesstohe.ac.uk) can provide a route to a science degree. Bear in mind, however, that some general science Access courses may not have enough content on a specific subject to qualify for a degree in that field. For some science degrees, a foundation or preliminary year at university may be a better preparation (The University of Bristol has such options for physics and chemistry). Contact the university's admissions tutors before enrolling on an Access course to discuss its suitability.

The University of Bristol and many others also have widening participation schemes and will make alternative offers (with reduced A-level requirements, for example) to students from schools or backgrounds that qualify. Again, get in touch with the university you're interested in to find out more about these.

Your personal statement

Once you've decided what subject you'd like to study and where you'd like to study it, the final step in the application process is your personal statement. Some science courses give little or no weighting to personal statements. But it's worth thinking carefully about what you write nevertheless because if it comes to a choice between two closely matched applicants, their personal statements may be what makes the difference.

A strong personal statement should convey your enthusiasm for the subject and show evidence of your engagement with the subject, such as attending talks or other extra-curricular activities. Many personal statements give examples of the books the applicant has read but the best ones show that they've thought carefully about the books' content.

The best advice for anyone with any uncertainty about any part of the application process, though, is to get in touch with the university you're interested in and ask.

Dr Ben Maughan
Reader in Astrophysics.

WHAT YOU CAN EXPECT FROM A STEM COURSE

Universities offer a wide range of science courses, not all of which you can study at school or college. So how do you know if such a course is right for you? We asked Dr Brenda Parker, the biochemical engineering admissions tutor at UCL, a few questions to give you more insight.

What can I expect in terms of lectures and lab work?

A good science degree will give you a mixture of practical and theory work, and the opportunity to learn by doing experiments. UCL's biochemical engineering classes are relatively small, so we can offer plenty of practical sessions. For us that's really important, as students need to grasp the fundamentals behind biology and process engineering.

UCL's undergraduate programme has molecular biology lab sessions in the first year as well as practicals in our pilot plant facility where students learn about fermentation and downstream processing. Rather than just having lectures, students at UCL learn through a combination of case studies, team projects and experiments. Leading industrialists and researchers regularly visit the department to lecture. Case studies are conducted in small teams, and personal and departmental tutors are available to provide support.

How will I be assessed?

We're always evolving when it comes to assessment. For engineers, exams are not always the best way to test a student's problem solving or adaptability. We use a mixture of examinations, individual reports, practical write-ups, coursework and oral presentations as assessment methods. Some courses, such as design, are entirely coursework or project based.

What would a typical week in the first year involve?

On the biochemical engineering course you'll have plenty of contact time and will be in university every day. A typical week for our year-one students might involve attending lecture-based courses, typically introductory courses for the discipline, or fundamental courses, such as mathematics. Lectures last two hours at UCL. One afternoon a week may be devoted to lab practicals. There may be additional tutorials or workshop-style sessions to support a particular course. Students tend to use the free time between lectures to work in groups.

Before each lecture we expect students to spend some time reading – certainly the students who get the most out of the lectures are those who have put in at least an hour's reading beforehand. Wednesday afternoons are kept free for sports!

Are science courses oversubscribed and harder to get a place on? If so, how can I improve my chances of getting a place?

Science courses are competitive, especially smaller ones with a strong practical component. Admissions tutors are on the lookout for students who show initiative and energy, someone that has organised their own work experience, for example, or participated in a citizen science course. Simply regurgitating material from textbooks isn't enough – you need to demonstrate your originality. Speaking as an admissions tutor, I want to see people with a genuine drive to take the degree and run with it, as well as the tenacity to stick out the challenging moments.

Is there scope for studying abroad?

Studying abroad is an option on our integrated masters course. Students decide during their third year and apply for the opportunity. Successful applicants spend their final year abroad working towards their degree. We support the student throughout the application process and the choice of modules. Our department offers exchanges with universities in Australia, Canada, Denmark, France, Germany, Hong Kong, Japan, Mexico, New Zealand, Portugal, Singapore, Spain, Sweden and the USA.

How about work placements?

UCL offers an integrated master course with a year in industry. If you choose this option, you'll spend your final year working in a company. Host companies might be in the pharmaceutical industry, food industry or cell and gene therapy R&D departments. The placements start in July and last for 12-15 months.

You'll have to find a placement, but UCL's biochemical engineering department will help you ensure it's a suitable one. The department has strong connections with industry and many of our partners advertise placements with us. Your personal tutor, course coordinator and the industry engagement team are all there to provide support. The placement can be in the UK or Europe and we've had students working with GSK, Merck Serono, Eli Lilly and Fujifilm Diosynth.

Dr Brenda Parker

Lecturer in biochemical engineering and undergraduate admissions tutor.

INCREDIBLE JOBS IN SCIENCE

Studying science doesn't mean you have to end up working in a lab. A science degree could get you started in all sorts of exciting careers. Here are just a few...

You could be a... Technical brewer
People all over the world have been brewing beer for centuries but we've yet to find the perfect pint. Perhaps there isn't one. But as a technical brewer you would be part of the search. Your working day would be spent sampling the best ingredients, researching the right recipes, testing the brewing method in order to ensure the quality of the finished product is consistent from the first pint to the last. Whether you're working in a microbrewery or for a major corporation, it's a hands-on role that requires you to master the physical means of production as well as understand exactly what's happening at the microbial level during the fermentation process – after all, your beer needs to taste good but it absolutely must be safe to drink.
And you'd need to study... microbiology

You could be a... Firework maker
In 1963, shortly after becoming the chemistry teacher at Kimbolton School in Cambridgeshire, the Reverend Ronald Lancaster began making fireworks in his spare time. Over the next 12 months, he established Kimbolton Fireworks, a small company to produce fireworks for local displays and develop ever more elaborate pyrotechnical devices. In the 50 years since then, Rev Lancaster's fountains, mines and candles have lit up the skies to mark the handover of Hong Kong in 1997, the opening of the 2012 Olympic Games and annual New Year's Eve celebrations in London and Edinburgh. Kimbolton Fireworks is now the only UK manufacturer of display fireworks, while Rev Lancaster MBE, a fellow of the Royal Society of Chemistry, was named as one of the UK's 100 leading practising scientists in 2014.
And you'd need to study... Chemistry

You could be a... Species conservation researcher
Have you ever considered being a superhero? If you became a species conservation researcher you could help save people from the effects of natural disasters, wars and even asteroid impacts. And you could do it without having to wear a silly cape. You might need a warm coat, though, because you'll be spending plenty of time in one of the world's seed banks, archiving, retrieving and examining the samples kept in cold storage in case of catastrophe. Plants provide us with food, fuel, medicine and building materials, and seed banks – such as those in Kew Gardens, London and Svalbard in Norway – serve as vaults where plant species can be protected from threats that might otherwise lead to their, and as a result our, eventual extinction.
And you'd need to study... Biology

You could be a... Rollercoaster designer
Suppose your job was to finding ways to balance potential and kinetic energy? That doesn't sound very exciting but what if striking the right balance meant people could fly down a track at breakneck speed, get hurled around tight bends and spin through loops and corkscrews? In other words, suppose you were rollercoaster designer. If you were, it wouldn't only be the energy of the cars on the track you'd need to balance, you'd also need to factor in the safety of the construction and the excitement it can deliver. Building rollercoasters, and making them go faster, climb higher and turn tighter, is a competitive business but the job can be as much of a thrill as the attractions themselves.
And you'd need to study... Mechanical engineering

You could be a... Computer games developer
Computer games grow bigger and more complex by the year, which means more and more people are involved in making them. Become a games developer and you could have a hand in modelling characters, animating cut-scenes or coding the games themselves. Gaming technology is developing so fast that there's always something new to learn. One day you might be trying to harness the capabilities of a new piece of hardware; the next you could be working on integrating elements of artificial intelligence and virtual reality. The scope for increasing your programming skills is constantly expanding but the most important thing you need to get into the games business is an understanding what makes people want to play a game – and that means playing and making them yourself.
And you'd need to study... Computer science.

University of BRISTOL

Study Chemistry at the University of Bristol

We are one of the largest Chemistry departments in the UK, home to nearly 700 undergraduate students.

Our globally-leading research is recognised as being amongst the top 5 UK chemistry departments and our award-winning Bristol ChemLabS initiative provides a unique teaching environment. Our undergraduates excel in this environment: 81% of our graduating students achieved at least a 2:1 in 2017.

Career prospects for our students are excellent. Chemistry with Industrial Experience graduates start on an average salary of £25,000 and physical science graduates from the University of Bristol earn above the Russell group median in all years following graduation. Only two other UK universities are more heavily targeted by top UK employers.

Bristol is a hugely attractive place to live, ranked first in the UK by the Sunday Times in 2017 and 2015.

More information on our programmes can be found at bris.ac.uk/chemistry/courses/undergraduate

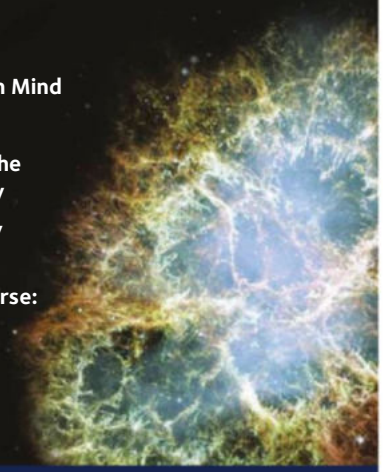
DEPARTMENT FOR CONTINUING EDUCATION

UNIVERSITY OF OXFORD

Join us in Oxford for a weekend of learning

Day and weekend schools on a variety of topics including:

- **The Extreme Universe**
- **Mission to Mars: Challenging the Human Mind**
- **Energy or Entropy?**
- **The Conscious Brain: the 15th Oxford Brain Day**
- **The Geological History of Britain**
- **The State of the Universe: The 40th Annual Astronomy Weekend**



@OxfordConted

www.conted.ox.ac.uk/weekendfocus

THE UNIVERSITY OF NOTTINGHAM: ENGINEERED AROUND YOU

University of Nottingham
UK | CHINA | MALAYSIA

TEF Gold

If you want to fit study into your busy life, Nottingham's distance learning and part-time engineering and architecture courses might be for you.

- All our departments are ranked in the UK top 10 (Guardian University Guide 2018)
- We have been awarded gold in the UK's Teaching Excellence Framework (TEF), the highest possible award, in recognition of consistently outstanding teaching and learning

We offer a range of flexible courses to fit around your work and family life:

- Professional Practice in Architecture Part 3 (part-time)
- Applied Ergonomics and Human Factors MSc (distance learning)
- Sustainable Energy and Entrepreneurship MSc (two years part-time)
- Usability and Human Computing Interaction PGCert (distance learning)

For more information, including course details and entry requirements, please visit

Nottingham.ac.uk/engineering/ flexible-learning

0115 951 5559

@NottinghamEngineering @UoNEngineering

Pearson

Enhance your teaching Career today

Pearson have exciting opportunities for Science teachers to become Standards Verifiers for our BTEC qualifications. This is a great way to get closer to the subject you love whilst gaining an insight into assessment.

To find out further information, please visit
www.edexcel.com/aa-recruitment

Image: Christof Van Der Walt